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FOR THE

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1891-'92.

IN THIRTY-EIGHT VOLUMES.

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REPORT

OF THE

SUPERINTENDENT

OF THE

U. S. COAST AND GEODETIC SURVEY

FOR THE

FISCAL YEAR ENDING JUNE 30, 1891,

IN TWO PARTS.

PART II.

APPENDICES RELATING TO THE METHODS, DISCUSSIONS, AND RESULTS OF THE COAST AND GEODETIC SURVEY.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1892.

PREFATORY NOTE.

The Report of the U. S. Coast and Geodetic Survey for the fiscal year 1891 is the first one in which the text has been arranged for publication in two parts.

Part I is in quarto form and contains the historical portion. It states progress in field and office work, gives estimates for future progress, and a report of expenditures during the fiscal year. It is accompanied by maps of general progress and by progress sketches more in detail.

Part II, it will be observed, is in octavo, and includes the professional papers relating to the methods, discussions, and results of the Survey which have been approved for publication during the year. Such illustrations as are needed accompany them.

The octavo form is more convenient and suitable for the scientific and professional papers, while the quarto form appears to be demanded for the statistical matter and the progress sketches. Since the latter are of less general interest than the former, in the future distribution of the Report Part II only will be sent, as it is believed that this will include all that is generally desired and in a much more compact and convenient form than that of the old quarto.

In special cases, where both parts are desirable, they will be sent.

T. C. MENDENHALL,
Superintendent.

U. S. COAST AND GEODETIC SURVEY REPORT FOR 1891.—PART II.

TITLES OF APPENDICES.

APPENDIX NO. 1—1891.

APPROXIMATE TIMES OF CULMINATIONS AND ELONGATIONS AND THE AZIMUTHS AT ELONGATION OF POLARIS FOR THE YEARS BETWEEN 1889 AND 1910.

Submitted for publication as a Bulletin November 21, 1889, by CHARLES A. SCHOTT, Assistant, and Chief of the Computing Division, and first published February 18, 1890.*

These tables of the times of culmination and of elongation of the Pole star and of its azimuth at elongation, for any time between the years 1889 and 1910 and for any place within the United States between latitudes 25° and 50° north, are designed for the use of the surveyor, to facilitate the determination of a meridian line and of the magnetic declination (variation of compass) by simple instrumental means and by a method easy of application. For this purpose the tables afford sufficient accuracy. They will also be found useful when preparing for or laying out work for a more refined determination of the astronomical azimuth as well as for the measure of the value of an eyepiece micrometer.

* Since these tables will be serviceable for their purpose until the year 1910, it has been deemed desirable to republish them in this annual report.

Local mean (astronomical) time of the culminations and elongations of Polaris in the year 1889.*

[Computed for latitude + 40° and longitude 6^h west from Greenwich.]

Date.		East elong'n.		Upper culm'n.		West elong'n.		Lower culm'n.	
1889.		h.	m.	h.	m.	h.	m.	h.	m.
Jan.	1	0	36·2	6	31·0	12	25·7	18	29·1
	15	23	37·0	5	35·7	11	30·4	17	33·8
Feb.	1	22	29·9	4	28·6	10	23·3	16	26·7
	15	21	34·6	3	33·3	9	28·1	15	31·4
Mar.	1	20	39·4	2	38·1	8	32·8	14	36·2
	15	19	44·4	1	43·1	7	37·7	13	41·1
Apr.	1	18	37·4	0	36·0	6	30·7	12	34·1
	15	17	42·4	23	37·1	5	35·7	11	39·0
May	1	16	39·5	22	34·2	4	32·9	10	36·1
	15	15	44·6	21	39·3	3	38·0	9	41·2
June	1	14	37·9	20	32·7	2	31·3	8	34·6
	15	13	43·0	19	37·8	1	36·4	7	39·7
July	1	12	40·4	18	35·2	0	33·8	6	37·1
	15	11	45·5	17	40·3	23	35·0	5	42·2
Aug.	1	10	39.0	16	33·8	22	28·4	4	35·7
	15	9	44·1	15	38·9	21	33·5	3	40·8
Sept.	1	8	37·5	14	32·3	20	26·9	2	34·2
	15	7	42·6	13	37·4	19	32·0	1	39·3
Oct.	1	6	39·7	12	34·5	18	29·1	0	36·4
	15	5	44·7	11	39·5	17	34·1	23	37·6
Nov.	1	4	37·9	10	32·7	16	27·3	22	30·8
	15	3	42·7	9	37·5	15	32·2	21	35·6
Dec.	1	2	39·7	8	34·5	14	29·2	20	32·6
	15	1	44·4	7	39·2	13	34·0	19	37·3

It will be noticed that for the tabular year two eastern elongations occur on January 10 and two western elongations on July 9; there are also two culminations on April 10 and on October 10.

The lower culmination either follows or precedes the upper culmination by $11^h\ 58^m\ {\cdot}1$.

For other dates and positions than those implied by the table we need to apply the following corrections:

To refer the tabular times to any year subsequent to the tabular year (1889) add $0^m\ {\cdot}33$ for every additional year.

To refer the tabular times, corrected as above, to any year in a quadriennium, observe that for first year after a leap-year the table is correct; for second year after a leap-year, add $0^m\ {\cdot}9$ to the tabular value; for third year after a leap-year add $1^m\ {\cdot}7$ to the tabular value; for leap-year *before* March 1, add $2^m\ {\cdot}6$ to the tabular value; for leap-year *from* and *after* March 1 subtract $1^m\ {\cdot}2$ from the tabular value.

To refer to any calendar day other than the first and fifteenth of each month, subtract $3^m\ {\cdot}94$ for every day between it and the preceding

* Counted from noon and from zero to twenty-four hours.

Approximate times of culminations and elongations of Polaris, etc.—Continued.

tabular day, or add $3^m \cdot 94$ for every day between it and the succeeding tabular day. The longitude correction will amount to $0^m \cdot 16$ subtractive for each hour west of 6^h.

To refer to any other than the tabular latitude between the limits of 25° and 50° north, add to the time of west elongation $0^m \cdot 13$ for every degree *south* of 40°, and subtract from the time of west elongation $0^m \cdot 18$ for every degree *north* of 40°; reverse these signs for corrections to times of east elongation.

It will be important to direct attention to the fact that the year 1900 is *not* a leap-year, and this must be kept in view when dealing with dates from and after March 1 of that year. The twentieth century begins after the expiration of December 31, 1900.

The deduced tabular times may generally be depended upon, with no greater error than $\pm\, 0^m \cdot 3$.

I.—*Azimuths of Polaris when at elongation for any year between*

Lat.	1890·0	1891·0	1892·0	1893·0	1894·0	1895·0	1896·0	1897·0	1898·0	1899·0	1900·0
°	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
+25	1 24·6	1 24·3	1 23·9	1 23·6	1 23·2	1 22·9	1 22·6	1 22·2	1 21·9	1 21·5	1 21·2
26	25·3	25·0	24·6	24·3	23·9	23·6	23·2	22·9	22·5	22·2	21·8
27	26·0	25·7	25·4	25·1	24·7	24·3	24·0	23·6	23·3	22·9	22·5
28	26·8	26·5	26·2	25·8	25·4	25·1	24·7	24·4	24·0	23·7	23·3
29	27·6	27·3	27·0	26·6	26·3	25·9	25·5	25·2	24·8	24·5	24·1
30	28·5	28·2	27·8	27·5	27·1	26·8	26·4	26·0	25·7	25·3	24·9
31	29·4	29·1	28·8	28·4	28·0	27·6	27·3	26·9	26·5	26·2	25·8
32	30·4	30·1	29·7	29·3	29·0	28·6	28·2	27·8	27·5	27·1	26·7
33	31·4	31·1	30·7	30·3	30·0	29·6	29·2	28·8	28·5	28·1	27·7
34	32·5	32·1	31·8	31·4	31·0	30·6	30·3	29·9	29·5	29·1	28·7
35	33·6	33·2	32·9	32·5	32·1	31·7	31·3	31·0	30·6	30·2	29·8
36	34·8	34·4	34·0	33·6	33·2	32·9	32·5	32·1	31·7	31·3	30·9
37	36·0	35·6	35·2	34·8	34·5	34·1	33·7	33·3	32·9	32·5	32·1
38	37·3	36·9	36·5	36·1	35·7	35·3	34·9	34·5	34·1	33·7	33·3
39	38·7	38·3	37·9	37·5	37·1	36·7	36·3	35·9	35·5	35·1	34·7
40	40·1	39·7	39·3	38·9	38·5	38·1	37·7	37·3	36·8	36·4	36·0
41	41·6	41·2	40·8	40·4	40·0	39·6	39·2	38·8	38·3	37·9	37·5
42	43·2	42·8	42·4	42·0	41·5	41·1	40·7	40·3	39·8	39·4	39·0
43	44·9	44·4	44·0	43·6	43·2	42·7	42·3	41·9	41·5	41·0	40·6
44	46·6	46·2	45·8	45·3	44·9	44·4	44·0	43·6	43·1	42·7	42·3
45	48·5	48·1	47·6	47·1	46·7	46·2	45·8	45·4	44·9	44·5	44·0
46	50·5	50·0	49·5	49·0	48·6	48·2	47·7	47·3	46·8	46·4	45·9
47	52·5	52·0	51·5	51·0	50·6	50·2	49·7	49·3	48·8	48·3	47·9
48	54·6	54·2	53·7	53·2	52·8	52·3	51·9	51·4	50·9	50·4	49.9
49	56·9	56·5	56·0	55·5	55·0	54·5	54·1	53·6	53·1	52·6	52.1
50	1 59·3	1 58·8	1 58·4	1 57·9	1 57·4	1 56·9	1 56·4	1 55·9	1 55·4	1 54·9	1 54·5

1889 and 1910, and for any latitude between +25° and +50°.

1901·0	1902·0	1903·0	1904·0	1905·0	1906·0	1907·0	1908·0	1909·0	1910·0	Lat.
° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	°
1 20·8	1 20·5	1 20·1	1 19·8	1 19·4	1 19·1	1 18·7	1 18·4	1 18·1	1 17·7	+25
21·5	21·1	20·8	20·5	20·1	19·8	19·4	19·1	18·7	18·4	26
22·2	21·9	21·5	21·2	20·8	20·5	20·1	19·8	19·4	19·1	27
23·0	22·6	22·2	21·9	21·6	21·3	20·9	20·5	20·1	19·8	28
23·8	23·4	23·0	22·7	22·4	22·1	21·7	21·3	20·9	20·5	29
24·6	24·2	23·9	23·5	23·1	22·8	22·4	22·1	21·7	21·3	30
25·5	25·1	24·7	24·4	24·0	23·6	23·2	22·9	22·5	22·2	31
26·4	26·0	25·6	25·3	24·9	24·5	24·1	23·8	23·4	23·1	32
27·3	27·0	26·6	26·2	25·9	25·5	25·1	24·7	24·3	24·0	33
28·4	28·0	27·6	27·2	26·9	26·5	26·1	25·7	25·3	25·0	34
29·4	29·0	28·7	28·3	27·9	27·5	27·1	26·8	26·4	26·0	35
30·5	30·1	29·8	29·4	29·0	28·6	28·2	27·9	27·5	27·1	36
31·7	31·3	30·9	30·5	30·1	29·7	29·3	29·0	28·6	28·2	37
33·0	32·6	32·2	31·8	31·4	31·0	30·6	30·2	29·8	29·4	38
34·3	33·9	33·5	33·1	32·7	32·3	31·8	31·4	31·0	30·6	39
35·6	35·2	34·8	34·4	34·0	33·6	33·2	32·8	32·4	32·0	40
37·1	36·7	36·2	35·8	35·4	35·0	34·6	34·2	33·8	33·4	41
38·6	38·2	37·7	37·3	36·9	36·5	36·0	35·6	35·2	34·8	42
40·2	39·8	39·3	38·9	38·5	38·1	37·6	37·2	36·8	36·3	43
41·8	41·4	41·0	40·5	40·1	39·7	39·2	38·8	38·4	37·9	44
43·6	43·2	42·7	42·3	41·8	41·4	40·9	40·5	40·1	39·6	45
45·5	45·0	44·6	44·2	43·7	43·2	42·7	42·3	41·9	41·4	46
47·4	46·9	46·5	46·0	45·6	45·1	44·6	44·2	43·7	43·3	47
49·5	49·0	48·6	48·1	47·7	47·2	46·7	46·3	45·8	45·3	48
51·7	51·2	50·7	50·2	49·8	49·3	48·8	48·4	47·9	47·4	49
1 54·0	1 53·5	1 53·0	1 52·5	1 52·0	1 51·5	1 51·0	1 50·6	1 50·1	1 49·6	50

The preceding table is computed with the mean declination of Polaris for each year; a closer result will be obtained by applying to the tabular values the following correction, which depends on the difference of the mean and the apparent place of the star:

For middle of—	Lat. 25°.	Lat. 40°.	Lat. 50°.	For middle of—	Lat. 25°.	Lat. 40°.	Lat. 50°.
	′	′	′		′	′	′
January	−0·3	−0·4	−0·4	July	+0·2	+0·3	+0·3
February	−0·3	−0·3	−0·4	August	+0·1	+0·1	+0·2
March	−0·1	−0·2	−0·2	September	0·0	−0·1	−0·1
April	0·0	0·0	0 0	October	−0·2	−0·3	−0·3
May	+0·2	+0·2	+0·2	November	−0·5	−0·6	−0·7
June	+0·2	+0·3	+0·3	December	−0·6	−0·8	−0·9

The deduced tabular azimuth (counted from the north) may generally be depended upon with no greater error than ± 0′·2.

In computing the tables, the mean places of Polaris were first accurately deduced from Newcomb's Catalogue of 1098 standard clock and zodiacal stars, Washington, 1881 (?), for five equidistant epochs, viz:

	α			δ		
	h.	*m.*	*s.*	°	′	″
1890	1	18	31·13	88	43	18·39
1895		20	30·08		44	52·68
1900		22	33·76		46	26·66
1905		24	42·48		48	00·31
1910		26	56·58		49	33·61

From these derived fundamental places those for each year were readily found by interpolation to third differences.

Among the simple methods for tracing out on the ground a true north and south line, and one demanding only a very slender instrumental outfit, is that given in Lalande's Astronomie and used by Andrew Ellicott in his boundary survey in 1785, and again recommended in the present century by Dr. Charles Davies.* It con-

* For reference and practical hints to the surveyor, see "Davies's Surveying," Van Amringe's edition of 1883, or the last edition of W. M. Gillespie's "Treatise on Land Surveying;" also instructions by the General Land Office to surveyors-general. [NOTE.—One of Ellicott's original notebooks, containing reference to the method, was inspected by the writer February 25, 1890. Ellicott remarks: "We learn from De la Land that the star ε Ursæ Majoris passed the meridian with the Pole star in July, 1751, and that it gained of the said Pole star 1′ 13″ 30‴ of time in ten years."—*Note added September 19, 1892.*] The problem involved is readily solved by first considering the spherical triangle, pole, Polaris, and second star, in which is given the angle at the pole or the difference of right ascensions of the stars and their polar distances, whence we deduce the angles at the stars. The condition of verticality demands that one or the other of these angles (according as we deal

Azimuths of Polaris when at elongation, etc.—Continued.

sists in watching for the time when Polaris and a given bright star come to the same vertical, and then, after a short lapse of time, given in a table, Polaris will be found exactly on the meridian, and hence can be referred to the horizon or to a mark placed there.

The verticality may be ascertained by a plumb line or by the vertical thread of a transit instrument; the method demands neither a graduated circle, nor a chronometer, nor an exact knowledge of the local time, an ordinary watch being sufficient to measure the short tabular interval.

Early in the present century the star Alioth (ϵ Ursæ Majoris) was favorably situated for use of the method; however, in 1850 the interval between times of verticality and of culmination already amounted to 17 minutes, which interval $\Delta\tau$ now (1890) has grown to $27^{m}\cdot8$ for Lower Culmination and to $28^{m}\cdot8$ for Upper Culmination; hence this star is no longer suitable, and ζ Ursæ Majoris or δ Cassiopeæ should now be substituted for it, both being in very favorable positions. ζ Ursæ Majoris or Mizar is the middle one of the three stars in the tail of the Great Bear, and δ Cassiopeæ is at the bottom of the first stroke of the W as frequently imagined to connect roughly the five brightest stars of this constellation. At present the Pole star culminates not quite one minute before it comes to the same vertical circle with ζ Ursæ Majoris, a fact indicated by a negative sign of $\Delta\tau$; but the two stars will culminate together two and a half years from now, with an annual increase of the interval of $0^{m}\cdot35$.

We have, with sufficient accuracy, for any latitude in the United States between, say, $\varphi = 24°$ and $49°$, and for either the Upper or the Lower Culmination of these bright stars, the value of $\Delta\tau$, as follows:

		m.	
For ζ Ursæ Majoris	in 1890	$-0\cdot9$	annual increase $0^{m}\cdot35$.
	in 1900	$+2\cdot6$	
For δ Cassiopeæ	in 1890	$+0\cdot1$	annual increase $0^{m}\cdot33$.
	in 1900	$+3\cdot4$	

In the higher latitudes, the Lower Culmination is preferable to the Upper, but in all cases special attention is to be paid to the adjustment of the vertical thread of the telescope and to the horizontality of its transverse axis, which is best done by sighting up and down a fine thread or wire from which a plummet is freely suspended.

with Upper or Lower Culmination) when subtracted from π should be a given angle in a second spherical triangle formed by the zenith, the pole, and one of the two stars, in which there is also known the co-latitude and the polar distance; solving it, we get the hour angle of Polaris.

APPENDIX NO. 2—1891.

ON THE DETERMINATION OF AN AZIMUTH FROM MICROMETRIC OBSERVATIONS OF A CLOSE CIRCUMPOLAR STAR NEAR ELONGATION BY MEANS OF A MERIDIAN TRANSIT,* OR BY MEANS OF A THEODOLITE WITH EYE-PIECE MICROMETER.

Submitted for publication as a Bulletin December 12, 1890, and first published February 26, 1891.†

Report on method and example of computation by CHARLES A. SCHOTT, Assistant, and Chief of the Computing Division.
Observations by A. T. MOSMAN, Assistant.

This method is capable of great accuracy of result, but demands that an elongation mark be set up in the direction of a vertical plane passing through a close circumpolar star when near elongation, and that an instrument, with an eyepiece micrometer, be available to measure micrometrically the angle between the vertical planes passing through the mark and star. Polaris is generally selected for this purpose, and even two elongation marks, one east and the other west of the meridian, may be set up for a double determination of the azimuth, in which case any small error in the star's declination as well as in the time and latitude of the place will be eliminated. It will be advantageous to locate the mark nearly in the direction of elongation so as to make the sum of the plus and minus micrometer measures balance as near as may be; the distance of the mark should be great enough not to require the sidereal focal adjustment of the telescope to be changed when pointing to it, and the appearance of the artificial light in size and intensity should resemble that of the star as nearly as possible. Before commencing observations the rotation axis of the telescope should be

* Davidson's Meridian and Equal Altitude Instrument (now generally known on the Survey as the Meridian Transit) is especially well adapted for this application. It is described and figured in Appendix No. 8, Coast Survey Report for 1867 (Plate No. 28); it is also shown on Plate No. 64, Appendix No. 14, Coast and Geodetic Survey Report for 1880. As used on the Survey it is made in two sizes; its principal characteristics are the split or double base frame, and the folding Y's, which give great portability to the instrument.

† The republication of this paper in its present form is owing to its permanent value as an exposition of one of the methods of the Survey.

leveled, the collimation of the telescope adjusted, and the two parallel vertical micrometer threads or lines adjusted to focus, and set truly vertical. To secure the horizontality of the axis either a spirit level is used or the star is observed alternately direct and reflected in mercury.

Though the method was understood and actually put in practice on the Survey as early as 1844, it does not appear to have come into general use, and Assistant Mosman devised it independently in September, 1880. It is not specially mentioned in the collection of azimuthal methods given in Appendix No. 14, Coast and Geodetic Survey Report for 1880. This limited use of the method may have been due to unfavorable conditions for locating the mark. The present account of it has been written with the view of bringing it anew to the attention of the observer. It may be remarked that the use of a collimator in the place of the mark was tried at an early time of the Survey (in 1844), and again later (in 1876), with an improved collimator, but its use never gave satisfaction, and its instability, on mountain tops especially, was plainly apparent.

The value of one turn of the micrometer may be determined, as usual, by observing the transits of a culminating star over the movable micrometer thread set ahead of the star successively by a small fraction of a turn only. As but a limited part of a turn is ever used by this method we need only the value of that part of the screw actually used in the observations for azimuth. Let $\triangle t$ or τ=the observed interval of time, in seconds, corresponding to one turn and δ=the star's declination; then considering the small range for which the micrometer is needed, we have, with sufficient accuracy, 1 turn $= 15\,\tau \cos\delta$, expressed in seconds of arc. Attention should be paid to the transit level, which should not change during the observations, or else is to be corrected for change; also a correction for rate of chronometer on sidereal time may be needed.

We have the hour angle t_e and the azimuth (counted from the north) A_e at elongation, by

$$\cos t_e = \tan\varphi \cot\delta \qquad \text{and} \qquad \sin A_e = \sec\varphi \cos\delta$$

and the chronometer time for $\left\{\begin{matrix}\text{W}\\\text{E}\end{matrix}\right.$ elongation $= \alpha \pm t_e +$ chronometer correction to sidereal time, $\pm$ when $\left\{\begin{matrix}\text{fast}\\\text{slow}\end{matrix}\right.$ of sidereal time

where φ = latitude of the place and α and δ the apparent right ascension and declination of the star at the time of elongation. For this time we have also the zenith distance from

$$\cos\zeta = \sin\varphi \operatorname{cosec}\delta$$

We find first the angle between the mark and the line of collimation, the reading of the latter being known after inversion of telescope on

On the determination of an azimuth from micrometric observations of a close circumpolar star, etc.—Continued.

the mark; next we measure micrometrically the angle between the vertical plane through the line of collimation and the star (Polaris usually); to reduce the latter measure to the plane of the horizon let $\triangle =$ the angular difference in divisions of the micrometer and $n =$ the value of one division in seconds of arc; then the angle in question referred to the horizon becomes $n \triangle \operatorname{cosec} \zeta$. The algebraic sum of these two angles gives the azimuthal difference between the mark and star. The correction for deviation of level is

$$\frac{d}{4}\Big[(w + w') - (e + e')\Big] \sin h \sec \varphi$$

where $d =$ value of one division of level in seconds of arc, w and e the readings of the west and east ends of the bubble before, and w' and e' similar readings after inversion of the telescope; for the factor $\sin h \sec \varphi$ we may substitute its approximate value $\tan \varphi$.

When a number of micrometer measures of the star near elongation are made they may be approximately reduced to the elongation by means of the simple formula

$$2 \sin^2 \tfrac{1}{2} \tau \tan A_e / \sin 1''$$

where $\tau = t_e - t$ or the difference between the chronometer time of elongation and the time of observation. For Polaris this expression will answer with sufficient accuracy for the limit $\tau = 15$ or 20 minutes, and roughly even for half an hour before or after elongation. A far more rigorous formula was developed in 1855 by Mr. James Main, formerly a member of the Computing Division;* it is as follows:

$$A_e - A = \sin A_e \cos A_e \operatorname{cosec}^2 t_e \frac{2 \sin^2 \frac{1}{2} \tau}{\sin 1''} (1 + \cot t_e \sin \tau)$$

where the result is expressed in seconds of arc; this formula will give results true within $0''\cdot05$ for $1^h\ 30^m$ from elongation for latitude 40° north. The rough expression

$$(2 \sin^2 \tfrac{1}{2} \tau / \sin 1'') \tan A_e$$

as well as the better expression

$$\sin (A_e - A) = \tan A_e \sin^2 \delta\, 2 \sin^2 \tfrac{1}{2} \tau$$

given in C. L. Doolittle's Practical Astronomy (New York, 1885), however, take no notice of the inequality in the azimuthal effect for the same value of τ *before* and *after* elongation. The most convenient and accurate form may be given as follows:

$$A_e - A = \tan A_e \sin^2 \delta \frac{2 \sin^2 \frac{1}{2} \tau}{\sin 1''} (1 + \cot t_e \sin \tau)$$

* Between November, 1851, and March, 1881.

The values of log. $(2 \sin^2 \frac{1}{2} \tau / \sin 1'')$ are found tabulated in many works on Practical Astronomy and Geodesy, *e. g.*, in Chauvenet's Manual on Spherical and Practical Astronomy, Volume II, where they are given up to half an hour. Tables of greater extent up to $1^h\ 40^m$ will be found in Dr. T. Albrecht's collection of formulæ and tables.* It is important to note that $\cot t_e \sin \tau$ changes sign according to the observed time being before or after elongation, viz:

$$\tau \text{ is } + \left\{ \begin{matrix} \text{before} \\ \text{after} \end{matrix} \right. \text{W. and } \left\{ \begin{matrix} \text{after} \\ \text{before} \end{matrix} \right. \text{E. Elongation.}$$

The effect of this term may be seen in the following short table, which refers to $\varphi = 38° \ 38'{\cdot}5$, and to observations of Polaris, September 14, 1885:

Reduction to Eastern Elongation for—

τ	Before elongation.	After elongation.
	$''$	$''$
15^m	12·85	12·88
20	22·83	22·90
25	35·65	35·79
30	51·29	51·53
45	115·06	115·88
60	203·81	205·74
75	317·07	320·80

The mean of the several measures reduced to elongation when algebraically combined with the angle, mark and star, will give the azimuthal angle $\triangle A$ between star and elongation, and consequently the azimuth of the mark $= A_e \pm \triangle A$.

The sign of $\triangle A$ will depend on the relative position of the mark and the vertical plane through the star supposed at east or west elongation, as the case may be; a rough diagram or projection of the hemisphere upon the plane of the horizon may be useful.

To (II.)† EXAMPLE OF RECORD AND REDUCTION.

STATION GOULD, OHIO (occupied eccentrically).

$\varphi = 38° \ 38' \ 30''{\cdot}3$ $\qquad \lambda = 82° \ 49' \ 55''{\cdot}8$ W.

Sept. 14, 1885, 4th set.
A. T. M., Observer.
Polaris near Eastern Elongation.

Instrument, the Meridian Telescope, No. 7; value of one division (100 d = 1 turn) of eyepiece micrometer $0''{\cdot}7830$, and of one division of transit level $1''{\cdot}40$

$$\left\{ \begin{matrix} \delta = +88° \ 41' \ 45''{\cdot}3 \\ \alpha = \quad 1^h \ 18^m \ 05.1 \\ \zeta = \quad 51° \ 20' \ 47'' \end{matrix} \right. \qquad \left\{ \begin{matrix} t_e = - \ 5^h \ 55^m \ 49^s{\cdot}7 \text{ and } \triangle T_0 = -0^h \ 01^m \ 35^s{\cdot}8 \\ T = \ 19 \ \ 20 \ \ 39 \cdot 6 \text{ and } \quad A_e = \ 1° \ 40' \ 10''{\cdot}97 \text{ E. of N.} \end{matrix} \right.$$

*Formeln und Hülfstafeln für geographische Ortsbestimmungen, etc., von Dr. Theod. Albrecht; Leipzig, 1873; see also "Nautische Tafeln," Pola, 1885.

†See arrangement of App. No. 14, Rep. for 1880.

On the determination of an azimuth from micrometric observations of a close circumpolar star, etc.—Continued.

Level.	Time by sid. chron'r B. 387.	Time from elongation.	Reduction to elongation.	Pos'n of telescope.	Micrometer reads— On mark.	On star.
					t. *d.*	
				E.	15 36·5	
					36·0	
					35·5	
					36·0	
					36·5	
W. E.					Mean 15 36·1	
d. *d.*	*h.* *m.* *s.*	*m.* *s.*	″			*t.* *d.*
23·0 29·0	19 34 40·5	14 00·9	11·25	E.		15 36·0
30·2 22·0	35 27·5	14 47·9	12·54			36·0
	35 49·5	15 09·9	13·17			37·0
	36 09·0	15 29·4	13·74			37·5
	36 35·0	15 55·4	14·52			39·0
						Mean 15 37·1
29·8 23·0	19 40 40·0	20 00·4	22·92	W.		15 36·5
22·3 30·5	40 58·5	20 18·9	23·63			36·0
	41 15·0	20 35·4	24·27			35·5
	41 30·6	20 51·0	24·89			34·0
	41 48·2	21 08·6	25·60			34·0
			Mean 18·65			Mean 15 35·2
				W.	15 49·0	
					49·0	
					50·0	
					49·0	
					48·0	
					Mean 15 49·0	

	t.
Telescope east, mark.	15·3610
Telescope west, mark.	15·4900
Collimation reads.	15·4255
Mark east of collimation.	·0645 = + 5″·05
Telescope east, collimation—star.	+ 15·4255
	— 15·3710
	+ 0·0545
Telescope west, star—collimation.	— 15·4255
	+ 15·3520
	— 0·0735
Star east of collimation ½ (5^d·45 — 7^d·35) × 1·003 †	= — 0″·95
Star east of mark.	— 6·00
Reduction to east elongation.	+ 18·65
Correction for level = $\frac{1·4}{8}$ (105·3 — 104·5) × 0·80	= + 0·11
Star at east elongation, east of mark.	+ 12″·76
A_e at east elongation.	1° 40′ 10·97
Mark east of north.	1 39 58·21

To which the correction for diurnal aberration or + 0″·31 is yet to be applied.

C. A. S.

† Where 1·003 = 0·783 cosec. 51° 20′ 47″

APPENDIX NO. 3—1891.

THE SECULAR VARIATION AND ANNUAL CHANGE OF THE MAGNETIC FORCE AT STATIONS OCCUPIED BY E. D. PRESTON, ASSISTANT U. S. COAST AND GEODETIC SURVEY, IN CONNECTION WITH THE U. S. ECLIPSE EXPEDITION TO THE WEST COAST OF AFRICA, IN 1889–'90, IN CHARGE OF PROF. D. P. TODD.

Discussion and report by C. A. SCHOTT, assistant, and chief of the Computing Division.

Submitted for publication March 16, 1891.

The records of the magnetic observations made by Assistant Preston during this expedition were turned over to the Computing Division of the Survey for reduction, and the results (deduced by Mr. L. A. Bauer, of the Computing Division) were reported by me under date of February 18, 1891. These results are given in Table II, following, and comprise declinations, dips, and intensities at fourteen stations. For special information about instruments, descriptions of stations, and sketches of localities, the reader is referred to the report of Assistant Preston, published as Appendix No. 12—1890, with the title: "Determinations of Gravity and the Magnetic Elements in connection with the U. S. Scientific Expedition to the West Coast of Africa, 1889–1890." Bulletin No. 22, published in June, 1891, may also be consulted.

TABLE I.—*Geographical positions of magnetic stations occupied by Assistant E. D. Preston in 1889–1890.*

	Name of station.	Latitude.			Longitude.		
		°	′		°	′	
0	Washington, U. S. Coast and Geodetic Survey Office, District of Columbia.	38	53·2	N.	77	00·5	W. from Gr.
1	Horta, Fayal Island, Azores.	38	31·8	N.	28	38·9	W.
2	Porto Grande, St. Vincent Island, Cape Verde.	16	53·3	N.	24	59·4	W.
3	Freetown, Sierra Leone, West Coast of Africa.	8	29·8	N.	13	14·7	W.
4	Elmina, Guinea, West Coast of Africa.	5	04·8	N.	1	20·3	W.
5	Loanda, Angola, West Coast of Africa.	8	48·8	S.	13	14·0	E.
6	Cabiri, Angola, West Coast of Africa.	8	47	S.	13	59	E.
7	Cape Town Observatory, Cape of Good Hope, west station.	33	56·1	S.	18	28·7	E.
8	Cape Town Observatory, Cape of Good Hope, southeast station.	33	56·1	S.	18	28·7	E.
9	Jamestown, St. Helena.	15	55·0	S.	5	43·7	W.
10	Longwood, St. Helena.	15	56·7	S.	5	41·5	W.
11	Georgetown, Ascension Island.	7	55·5	S.	14	25·0	W.
12	Green Mountain, Ascension Island.	7	56·7	S.	14	21·5	W.
13	Bridgetown, Barbados.	13	04	N.	59	36	W.
14	Nonsuch Island, Bermuda.	32	20·6	N.	64	39·2	W.

The secular and annual changes of the magnetic force at stations occupied in connection with the Eclipse Expedition, 1889–'90, etc.—Continued.

TABLE II.—*Results of magnetic observations for declination, dip, horizontal and total intensity (in dynes).*

	Name of place.	Year.	Date.	Declination.*	Date.	Dip.	Date.	Horizontal intensity.	Total intensity.
				° ′		° ′			
0	Washington.	1889	Sept. 24, 25, 26	4 15·1 W.	Sept. 24, 25, 26	70 25·8 N.	Sept. 24, 25, 26	0·2012	0·6007
1	Horta.	1889	Nov. 2, 3	25 52 W.	Nov. 2, 3	64 13·8 N.	Nov. 2, 3	0·2073	0·4768
2	Porto Grande.	1889	Nov. 11	20 45 W.	Nov. 11	42 12·3 N.	Nov. 11	0·2738	0·3696
3	Freetown.	1889	Nov. 19	19 17 W.	Nov. 19	15 24·2 N.	Nov. 19	0·3193	0·3312
4	Elmina.	1889	Nov. 27, 28	17 10 W.	Nov. 27, 28	0 35·4 N.	Nov. 27, 28	0·3102	0·3103
5	Loanda.	1889	Dec. 14, 15, 16	17 46 W.	Dec. 14, 15, 16	34 10·9 S.	Dec. 14, 15, 16	0·2633	0·3183
6	Cabiri.	1889	Dec. 22, 23	18 13 W.	Dec. 22, 23	33 53·4 S.	Dec. 21, 22	0·2635	0·3174
7	Cape Town, west station.	1890	Jan. 21, 22, 23	29 32 W.	Jan. 21, 22, 24	57 15·2 S.	Jan. 21, 22, 23	0·1916	0·3542
8	Cape Town, southeast station.	1890	Jan. 31, Feb. 1	29 40 W.	Jan. 31, Feb. 1	57 15·3 S.	Jan. 31, Feb. 1	0·1919	0·3548
9	Jamestown.	1890	Feb. 24, 25	23 57 W.	Feb. 24, 25	29 39·0 S.	Feb. 24, 25	0·2493	0·2869
10	Longwood.	1890	Mar. 3, 4, 5	24 36 W.	Mar. 3, 4, 5	31 11·0 S.	Mar. 3, 4, 5	0·2287	0·2672
11	Georgetown.	1890	Mar. 21, 22, 23	22 36 W.	Mar. 20, 21, 22	11 37·9 S.	Mar. 21, 22, 23	0·2755	0·2813
12	Green Mountain.	1890	Mar. 30, 31, Apr. 1	23 24 W.	Mar. 29, 30, 31	12 11·7 S.	Mar. 29, 30, 31	0·2676	0·2738
13	Bridgetown.	1890	May 2, 4, 8, 9	1 12 W.	May 1, 2, 4	43 08·2 N.	May 1, 2, 4	0·3023	0·4143
14	Nonsuch Island.	1890	May 23, 24, 25, 26	8 04 W.	May 21, 22, 23	64 47·6 N.	May 21, 23, 24, 25	0·2333	0·5478

* The results refer to the mean value of the day.

In order to facilitate the application of the above results, and to increase their usefulness, it will be necessary to compare them with such older observations at these stations as may have been made, and to deduce from these comparisons the law of secular variation, or in cases of insufficient observations to determine the annual change. The results will then be directly available, and will aid in the construction of isomagnetic curves for any recent epoch over the region of the North and South Atlantic covered by our observations.

The writer is aware of the incompleteness of the older results here collected, as must necessarily be the case in any attempt involving foreign stations, but it is to be hoped that those having local knowledge or better facilities for collection may be induced to contribute something towards the general stock of information.

We shall take up the stations in the chronological order given in the table, but discuss separately the declination, dip, and intensity changes. Beginning with the declinations, this part will simply form an addition to my paper on the Secular Variation of the Magnetic Declination in the United States and at some foreign stations, "Appendix No. 7, Report for 1888, Washington, 1890," and the results when generalized will thus extend over a largely increased area. For the annual changes of dip and intensity within the United States the reader may consult Appendix No. 6, Report for 1885. For treatment and notation see these appendices.

(*o*) *Washington, D. C.*—Position of Coast and Geodetic Survey Office, $\varphi = +38^\circ\ 53'\cdot2$, $\lambda = 77^\circ\ 00'\cdot5$ W. We have 34 values between 1750 and 1889, as given in Appendix No. 7, Report for 1888. This includes Mr. Preston's station and gives for the annual increase of west declination $2'\cdot4$ for the epoch 1890, and $2'\cdot0$ for the epoch 1895, according to the formula $D = +2^\circ\cdot73 + 2\cdot57 \sin(1\cdot45m - 21^\circ\cdot6) + 0\cdot07 \sin(12m + 27^\circ)$, which differs slightly from that given on p. 225 in the coefficient of the second periodic term, the present value being preferred. We have as usual $m = t - 1850\cdot00$.

(*1*) *Horta, Fayal Island, Azores.*—Position of Castle of Santa Cruz,

$$\varphi = +38^\circ\ 31'\cdot8, \qquad \lambda = 28^\circ\ 38'\cdot9 \text{ W.}$$

The secular and annual changes of the magnetic force at stations occupied in connection with the Eclipse Expedition, 1889–'90, etc.—Continued.

We have the following data:

No.	Date.	Declination.	Observer.
--	1497 or 1498.	Small east declination.	Sebastian Cabot noted "no variation" in a position on the meridian 110 miles west of the island of Flores [and in estimated latitude 46° or 47°.—SCH.], U. S. Coast and Geodetic Survey Bulletin No. 6, May, 1888. [Neither Martin Behaim, the cartographer, who resided several years (between 1486 and 1492) at Fayal, nor Christopher Columbus, who was at Santa Maria in February, 1493, have apparently left any information respecting the variation at these islands.—SCH.]
1	1589, Sept. 13–22.	° ′ 3 05 E.	E. Wright, at Fayal. Untersuchungen über den Magnetismus der Erde von Christopher Hansteen, Christiania, 1819. [Hansteen's isogonic chart for 1600 gives 1½° east, and according to the Arcano del Mare the easterly declination about 1630 was small.–SCH.]
2	1600.	0 00	At Flores Island: Hansteen's Magnetismus der Erde, 1819.
	1610.	1 40 E.	J. Davis, at Santa Maria Island.
3	1700.	5 10 W.	Edm. Halley, Tabula Nautica, Var'm Mag'm Index (Greenwich astronomical observations for 1869).
4	1775, July 14.	22 07 W.	Capt. Cook, at Fayal. Hansteen's Magnetismus der Erde, 1819.
5	1829.	25 55 W.	Capt. Lütke, at Fayal. Sir Edw. Sabine in Phil. Trans. Roy. Soc., Vol. 165, for 1875, London, 1876.
6	1842.	27 00 W.	Capt. Vidal, at Pico. [Vidal found 27° 30′ W. at Flores in 1844, hence the declination at Fayal in 1842 could not have differed much from 27° W.—SCH.]
7	1889, Nov. 2, 3.	25 52 W.	E. D. Preston, assistant U. S. Coast and Geodetic Survey, at Horta. [The declination is reduced to mean of day, as at all his other stations.—SCH.] N. B.—A chart of the Azores, published by the U. S. Hydrographic Office in July, 1890, states "variation decreasing 3′ annually."

The observations are represented by the formula:

$$D = +12^\circ{\cdot}43 + 14{\cdot}97 \sin (0{\cdot}750m + 88^\circ{\cdot}6)$$

a positive sign of D indicating west declination; the observed and computed values compare as follows:

No.	Date.	Observed D.	Computed D.	O — C
		°	°	°
1	1589·7	— 3·09	— 1·91	—1·18
2	1605·0	— 0·83	— 2·48	+1·65
3	1700·0	+ 5·17	+ 6·37	—1·20
4	1775·5	+22·12	+20·51	+1·61
5	1829·5	+25·92	+26·76	—0·84
6	1842·5	+27·00	+27·28	—0·28
7	1889·8	+25·87	+25·60	+0·27

According to our formula the period is 480 years, the maximum east declination occurred about 1612, amount 2°·5, and the maximum west in 1852, amount 27°·4. Annual decrease in 1890, 5′·6, and in 1895, 6′·3.

(2) *Porto Grande, St. Vincent Island, Cape Verde Islands.*—Position of Porto Grande

$$\varphi = +16^\circ\ 53'\cdot3 \qquad \lambda = 24^\circ\ 59'\cdot4\ \text{W.}$$

We have the following data:

No.	Date.	Declination.	Observer.
		° ′	
1	1615 (about).	0	[According to the Arcano del Mare, the declination at these islands was about zero in 1615 ± 15 years, as estimated by me; before this date the declination was easterly, as shown by Hansteen's chart for 1600.—SCH.]
2	1700.	3¾ W.	Edm. Halley, Tabula nautica, etc.
3	1822.	15 03 W.	Duperrey, at San Antonio Island. This island is close to St. Vincent Island, hence the declination may also be used for the latter. Phil. Trans. Roy. Soc., Vol. 165, 1875; London, 1876. [The observations at Porto Praya, St. Iago Island, indicate an increase of west declination between 1822 and 1843 of about 2′ per annum.—SCH.]
4	1873, July 31,	18 40 W.	At Porto Grande, Voyage of H. M. S. Challenger, Vol II, pp. 27, 58. [Second value not used.—SCH.]
	Aug. 2.	17 19·8 W.	
5	1876, Apr. 19.	19 54 W.	At St. Vincent, swinging.
	Apr. 22.	18 52 W.	On St. Vincent Island, voyage of H. M. S. Challenger, Vol. II, pp. 43, 46, 70. [Second value not used.—SCH.]
6	1884, Nov. 10.	19 47 W.	Lieut. J. D. Adams, U. S. S. Kearsarge, in latitude + 16° 19′ and longitude 24° 49′ W. Naval Prof. Papers No. 19: Washington, 1886.
7	1889, Nov. 11.	20 45 W.	E. D. Preston, Assistant, U. S. Coast and Geodetic Survey, at Porto Grande.

The above observations are represented by the formula

$$D = +10^\circ\cdot51 + 10\cdot27 \sin (0\cdot590\,m + 44^\circ\cdot0)$$

and the observed and computed values compare as follows:

No.	Date.	Observed D.	Computed D.	O — C
		°	°	°
1	1615·0	0·00	+ 0·27	—0·27
2	1700·0	+ 3·75	+ 3·31	+0·44
3	1822·5	+15·05	+15·30	—0·25
4	1873·6	+18·67	+19·21	—0·54
5	1876·3	+18·87	+19·36	—0·49
6	1884·8	+19.78	+19·78	0·00
7	1889·9	+20·75	+20·00	+0·75

The secular and annual changes of the magnetic force at stations occupied in connection with the Eclipse Expedition, 1889–'90, etc.—Continued.

According to the formula the period is 610 years, but this is very uncertain, since neither the last minimum west nor the maximum west (as expected) has become known; in fact, the expression is but a rough approximation.

The maximum east occurred about 1623, amount 0°·2 east; the maximum west is expected about 1928, amount 20°·8 west. Annual increase in 1890, 2′·4, and in 1895, 2′·1.

(3) *Freetown, Sierra Leone.*—Position

$$\varphi = +8^\circ\ 29'\cdot 8 \qquad \lambda = 13^\circ\ 14'\cdot 7 \text{ W.}$$

We have the following observations:

No.	Date.	Declination.	Observer.
		° ′	
1	1826.	18 48 W.	Capt. Owen } Sir Edw. Sabine in Phil. Trans. Roy. Soc., Vol., 165, for 1875: London, 1876.
2	1836.	19 23 W.	Capt. Vidal }
	1836.	19 36 W.	Capt. Denham }
3	1889, Nov. 19.	19 17 W.	E. D. Preston, Assistant, U. S. Coast and Geodetic Survey; at Freetown.

The above data are insufficient to deduce any value for annual change.

(4) *Elmina, Gold Coast.*—Position of Fort St. George

$$\varphi = +5^\circ\ 04'\cdot 8 \qquad \lambda = 1^\circ\ 20'\cdot 3 \text{ W.}$$

We have the following observations:

No.	Date.	Declination.	Observer.
		° ′	
1	1838.	20 11 W.	Capt. Vidal, Phil. Trans. Roy. Soc., Vol. 165, for 1875; London, 1876.
2	1889, Nov. 27, 28.	17 10 W.	E. D. Preston, Assistant, U. S. Coast and Geodetic Survey.

No deduction for annual change can be made from these data.

(5) *Loanda, Angola.*—Position of St. Paul de Loanda, flagstaff Fort San Miguel

$$\varphi = -8^\circ\ 48'\cdot 3 \qquad \lambda = 13^\circ\ 13'\cdot 1 \text{ east}$$

and of magnetic station

$$\varphi = -8^\circ\ 48'\cdot 8 \qquad \lambda = 13^\circ\ 14'\cdot 0 \text{ east.}$$

We have the following observations:

No.	Date.	Declination.	Observer.
		° ′	
1	1825.	22 00 W.	Captain Owen, Phil. Trans. Roy. Soc., Vol. 167, Part II: London, 1878.
2	1889, Dec. 14, 15, 16.	17 46 W.	E. D. Preston, Assistant, U. S. Coast and Geodetic Survey.

No deduction can be made from these data respecting the annual change, although the three African stations, Nos. 3, 4, and 5, all apparently point to a decreasing west declination for the present time.

(6) *Cabiri, Angola.*—Position

$$\varphi = -8^\circ\ 47' \qquad \lambda = 13^\circ\ 59'\ \text{E.}$$

At this place we have only Assistant Preston's observation in December, 1889, already given.

(7, 8) *Cape Town, Cape of Good Hope.*—Position of astronomical observatory

$$\varphi = -33^\circ\ 56'\cdot 1 \qquad \lambda = 18^\circ\ 28'\cdot 7\ \text{E.}$$

At this station we have the following observations:

No.	Date.	Declination.	Observer.
		° ′	
1	1605	0 30 E.	The observed values are taken from "Cape Observations, Mag'c and Met'c, Vol. I, p. lx," as given by Walker in his "Terrestrial and Cosmical Magnetism," Cambridge (England), 1866, excepting values Nos. 6, 24, and 25. See also Encyclopædia Britannica, 9th edition, 1883, Art. Meteorology.
2	1609	0 12 W.	
3	1622	2 00 W.	
4	1675	8 14 W.	
5	1691	11 00 W.	
6	1700	10¼ W.	Edm. Halley; Tabula Nautica, etc.
7	1751	19 15 W.	
8	1775	21 14 W.	
9	1788	24 04 W.	
10	1792	24 31 W.	
11	1818	26 31 W.	
12	1836	28 30 W.	
13	1839	29 09 W.	
14	1841·5	29 06·2 W.	British Colonial Magnetic Observatory, Cape of Good Hope. The declinations for the years 1841–1850 differ but slightly from the values given by Walker, who deduced his results for 1841, 1846, and 1850 from observations of 9, 7, and 8 months, respectively.
15	*1842·5	29 05·9 W.	
16	1843·5	29 06·0 W.	
17	1844·5	29 06·2 W.	
18	1845·5	29 07·4 W.	
19	1846·5	29 08·7 W.	
20	1847·5	29 12·4 W.	
21	1848·5	29 14·0 W.	
22	1849·5	29 16·2 W.	
23	1850·5	29 18·8 W.	
24	1857·5	29 34 W.	Austrian frigate Novara.
25	1873·9	30 04 W.	H. M. S. Challenger Narrative, Vol. II, p. 29.
26	1890·1	29 32 W.	E. D. Preston, Assistant U. S. Coast and Geodetic Survey. The result at the western station.

* Belcher's observation of 1842, 29° 10′ W., was not used, the Observatory value being preferred.—SCH.

The secular and annual changes of the magnetic force at stations occupied in connection with the Eclipse Expedition, 1889–'90, etc.—Continued.

These observations are satisfied by the formula:

$$D = +14^\circ{\cdot}63 + 15^\circ{\cdot}00 \sin(0{\cdot}610m + 77^\circ{\cdot}7)$$

as shown by the following comparison of observed and computed values:

No.	Date.	Observed D.	Computed D.	O—C	No.	Date.	Observed D.	Computed D.	O—C
		°	°				°	°	
1	1605·5	— 0·50	+ 0·41	—0·91	14	1841·5	+29·10	+28·94	+0·16
2	1609·5	+ 0·20	0·62	—0·42	15	1842·5	29·10	28·99	+0·11
3	1622·5	2·00	1·50	+0·50	16	1843·5	29·10	29·03	+0·07
4	1675·5	8·23	7·43	+0·80	17	1844·5	29·10	29·08	+0·02
5	1691·5	11·00	9·74	+1·26	18	1845·5	29·12	29·12	0·00
6	1700·0	10·25	11·00	—0·75	19	1846·5	29·14	29·18	—0·04
7	1751·5	19·25	19·16	+0·09	20	1847·5	29·21	29·20	+0·01
8	1775·5	21·23	22·64	—1·41	21	1848·5	29·23	29·24	—0·01
9	1788·5	24·08	24·31	—0·23	22	1849·5	29·27	29·27	0·00
10	1792·5	24·52	24·79	—0·27	23	1850·5	29·31	29·30	+0·01
11	1818·5	26·52	27·43	—0·91	24	1857·5	29·57	29·50	+0·07
12	1836·5	28·50	28·69	—0·19	25	1873·9	30·07	29·62	+0·45
13	1839·5	+29·15	28·84	+0·31	26	1890·1	+29·53	29·29	+0·24

The formula demands a period of 590 years and gives a maximum east declination about 1575, amount $-0^\circ{\cdot}3$, and a maximum west declination in 1870, amount $+29^\circ{\cdot}6$. The annual decrease in 1890 is $2'{\cdot}0$, and in 1890 $2'{\cdot}5$.

(9, 10) *St. Helena.*—Position of anchorage, off Jamestown:

$$\varphi = -15^\circ\ 55'{\cdot}0 \qquad \lambda = 5^\circ\ 43'{\cdot}7 \text{ west},$$

and of the Magnetic Observatory near Longwood, established by the British Government,

$$\varphi = -15^\circ\ 56'{\cdot}7 \qquad \lambda = 5^\circ\ 41'{\cdot}5 \text{ west}.$$

We have the following observed declinations:

No.	Date.	Declination.	Observer.	
		° ′		
1	1610.	7 13 E.	Davis	These values are taken from "Magnetical and Meteorological Observations," St. Helena, 1844–1849, Vol. II, p. vi, London, 1860. By Maj. Gen. Edw. Sabine.
2	1677.	0 40 E.	Halley	
3	1691.	1 00 W.	Halley	
4	1724.	7 30 W.	Mathew	
5	1775.	12 18	Wales	
6	1789.	15 30	Hunter	
7	1796.	15 48	Macdonald	
8	1806.	17 18	Krusenstern	
--	1836.	18 00	Fitzroy: Phil. Trans. Roy. Soc., Vol. 167, Part II, p. 478, London, 1878. [Not used; locally affected.—SCH.]	
9	1839.	22 17	Du Petit Thouars	Authority as for Nos. 1–8.
10	1840.	22 53	Ross	
11	1845.	23 15	At Longwood Observatory the total change in declination observed between 1840 and 1845, inclusive, was 23° 27′ — 22° 53′ = 34′, or annual increase 7′, nearly; hence interpolated value for 1845, from Ross's observations, 23° 27′, and from Bérard's observations, 23° 04′, mean 23° 15′ west adopted.	
12	1846.	23 11	Bérard, authority as for No. 10.	
13	1890, Feb. 24, 25.	23 57 W.	E. D. Preston, Assistant U. S. Coast and Geodetic Survey, at Jamestown.	

These observations are satisfied by the equation:

$$D = +8^\circ\cdot 90 + 15^\circ\cdot 31 \sin (0\cdot 618m + 65^\circ\cdot 1)$$

and the observed and computed values compare as follows:

No.	Date.	Observed D.	Computed D.	O—C
		°	°	°
1	1610·5	— 7·22	— 6·29	—0·93
2	1677·5	— 0·67	— 1·25	+0·58
3	1691·5	+ 1·00	+ 0·60	+0·40
4	1724·5	+ 7·50	5·59	+1·91
5	1775·5	+12·30	13·91	—1·61
6	1789·5	+15·50	16·02	—0·52
7	1796·5	+15·80	17·01	—1·21
8	1806·5	+17·30	18·36	—1·06
9	1839·5	+22·28	21·97	+0·31
10	1840·5	+22·88	22.05	+0·83
11	1845·5	+23·25	22·45	+0·80
12	1846·5	+23·19	22·53	+0·66
13	1890·1	+23·95	24·21	—0·26

The formula demands a period of 582½ years and gives a maximum east declination about 1599, amount 6°·4 E., and a maximum west declination in 1890, amount 24°·2 W. The annual change in 1890 was nearly zero; in 1895 it will be a decrease of 0′·5.

The secular and annual changes of the magnetic force at stations occupied in connection with the Eclipse Expedition, 1889–'90, etc.—Continued.

(11, 12) *Ascension Island.*—Position of Georgetown.

$$\varphi = -7^\circ\ 55'\cdot 5 \qquad \lambda = 14^\circ\ 25'\cdot 0\ \text{W}.$$

and of Green Mountain:

$$\varphi = -7^\circ\ 56'\cdot 7 \qquad \lambda = 14^\circ\ 21'\cdot 5\ \text{W}.$$

At this island the local disturbances in the magnetic distribution are very great.

We have the following observations, viz:

No.	Date.	Declination.	Observer.	
		° ′		
--	1700.	2 0 E.	Halley, in his "Tabula Nautica," etc.	
--	1830.	20 10 W.	Foster.	Gen. Sir Edw. Sabine in Phil. Trans. Roy. Soc., Vol. 167, part II, London, 1878.
1	1836.	17 36 W.	Fitz Roy.	
2	1839.	18 31 W.	Du Petit Thouars.	
3	1842.	19 16 W.	Bérard.	
4	1846.	19 16 W.	Belcher.	
5	1861.	21 45 W.	Denham.	
6	1863.	21 38 W.	H. M. S. Hecaté.	
7	1876, March 29.	23 06 W.	H. M. S. Challenger, Narrative, Vol. II, p. 43.	At Georgetown.
	1876, March 30.	22 32 W.		At Green Mountain.
	1876, April 3.	22 41 W.		At sea, swinging.
8	1890, March 21–23.	22 36 W.	E. D. Preston, assistant U. S. Coast and Geodetic Survey.	At Georgetown,
	1890, March 30, 31, April 1.	23 24 W.		At Green Mountain.

Captain Foster's value of 1830 would seem to be affected with a deflection of about 3°, and the discrepancy in the observations by the Challenger and by Mr. Preston is likewise due to local irregularity; probably values at Green Mountain are more nearly normal than the values at Georgetown, as we may judge from the result of the Challenger when swinging; mean values, however, were preferred for the present.

The expression $D = +20^\circ\cdot 34 + 0\cdot 142\ m - 0\cdot 0020\ m^2$ represents the observations, as follows:

No.	Observed D.	Computed D.	O.—C.	No.	Observed D.	Computed D.	O.—C.
	°	°	°		°	°	°
1	+17·60	+18·06	−0·46	5	+21·75	+21·71	+0·04
2	18·52	18·63	−0·11	6	21·63	21·89	−0·26
3	19·27	19·16	+0·11	7	22·77	22·69	+0·08
4	19·27	19·82	−0·55	8	23·00	22·82	+0·18

The maximum west declination, accordingly, occurred in 1885; amount, 22°·9 W. The annual decrease was 1′·1 for 1890, and for 1895 it will be 2′·3.

(13) *Bridgetown, Barbados.*—Position of Rickett's Battery:

$$\varphi = +13^\circ\ 05'\cdot7 \qquad \lambda = 59^\circ\ 37'\cdot3\ \mathrm{W.}$$

and of magnetic station:

$$\varphi = +13^\circ\ 04' \qquad \lambda = 59^\circ\ 36'\ \mathrm{W.}$$

The observations at this island will be found collected and discussed in Appendix No. 7, Coast and Geodetic Survey Report for 1888. The changes made in the table on p. 256 (*ibid.*) are the introduction of the value $5\frac{1}{3}^\circ$ east for 1700, according to Edm. Halley's Tabula Nautica, etc., and the substitution of Mr. Preston's value of 1890 for the value of 1884, which latter had only been used temporarily in the absence of a later value.

The expression $D = -1^\circ\cdot88 + 2\cdot83 \sin (0\cdot95\ m + 24^\circ\cdot6)$ represents the observations as follows:

Year.	Observed D.	Computed D.	O.—C.
	°	°	°
1700·0	−5·33	−4·38	−0·95
1726·5	−3·92	−4·71	+0·79
1760·4	−4·50	−4·34	−0·16
1761·3	−3·78	−4·32	+0·54
1833·5	−1·48	−1·44	−0·04
1839·5	−1·22	−1·17	−0·05
1846·5	−1·45	−0·85	−0·60
1871·5	−0·58	+0·12	−0·70
1890·3	+1·20	+0·64	+0·56

The formula supposes a period of 379 years, with a maximum west declination in 1919, amount $1^\circ\cdot0$ W. In 1890 the annual change was $1'\cdot3$; in 1895 it will be $1'\cdot1$, increasing west.

(14) *Nonsuch Island, Bermuda.*—Position of the island:

$$\varphi = +32^\circ\ 20'\cdot6 \qquad \lambda = 64^\circ\ 39'\cdot2\ \mathrm{W.}$$

The observations made in the Bermuda Islands will be found collected in Appendix No. 7, Coast and Geodetic Survey Report for 1888, pp. 222, 223. To these we add Mr. Preston's determination of 1890. The local disturbances of the Bermudas were investigated by Staff Commander E. W. Creak, R. N., in 1886, but his researches do not extend over the eastern part of the group of islands. No correction for local deflection can therefore be assigned, and we shall use the value as observed.:

The expression

$$D = +6^\circ\cdot926 + 0\cdot0107m + 0\cdot00045m^2$$

represents the observations very well. It is, however, inadmissible, for

The secular and annual changes of the magnetic force at stations occupied in connection with the Eclipse Expedition, 1889–'90, etc.—Continued.

the reason that it demands a western minimum about 1838, amount 6°·86 west. A minimum about this time is contradicted by all surrounding stations, which show that it must have taken place much earlier and in the preceding century. The curvature being slight and in the wrong direction, there remains only a representation by a straight line for the present. I adopt therefore:

$$D = +7°{\cdot}08 + 0{\cdot}0202m,$$

which represents the observations as follows:

Year.	Observed D.	Computed D.	O.—C.
	°	°	°
1831·5	+6·98	+6·70	+·28
1837·5	6·67	6·83	—·16
1845·8	7·02	7·00	+·02
1846·5	6·88	7·01	—·13
1873·3	7·21	7·55	—·34
1876·5	7·75	7·61	+·14
1890·4	+8·07	+7·90	+·17

The annual increase of west declination is 1′.2, but for 1895 it will probably be 1′·5.

In the following table I have brought together some of the principal results obtained in the discussion of 1888 and in the present investigation.

Station.	Lat.	Long.	Declination, + west, — east.	Annual change. [+ increasing west.] 1890.	1895.
NORTH ATLANTIC.	° ′	° ′	° ° °	′	′
Halifax, Nova Scotia.	44 39·6 N.	63 35·3 W.	D = + 16·18 + 4·53 sin (1·00m + 46·1)	+0·3	—0·1
Horta, Azores.	38 31·8 N.	28 38·9 W.	D = + 12·43 + 14·97 sin (0·750m + 88·6)	—5·6	—6·3
St. Georges, Bermuda.	32 22·6 N.	64 40·6 W.	D = + 7·08 + 0.0202m	+1·2	(+1·5)
Savannah, Ga.	32 04·9 N.	81 05·5 W.	D = — 2·13 + 2·55 sin (1·40m — 40·5)	+3·6	+3·4
Porto Grande, Cape Verde.	16 53·3 N.	24 59·4 W.	D = + 10·51 + 10·27 sin (0·590m + 44·0)	+2·4	+2·1
Bridgetown, Barbados.	13 05·7 N.	59 37·3 W.	D = — 1·88 + 2·83 sin (0·95m + 24·6)	+1·3	+1·1
SOUTH ATLANTIC.					
Georgetown, Ascension.	7 55·5 S.	14 25·0 W.	D = + 20·34 + 0·142m — 0·0020m²	—1·1	—2·3
Jamestown, St. Helena.	15 56·7 S.	5 41·5 W.	D = + 8·90 + 15·31 sin (0·618m + 65·1)	0·0	—0·5
Rio de Janeiro, Brazil.	22 54·8 S.	43 09·5 W.	D = + 2·19 + 9.91 sin (0·80m — 10·4)	+7·7	+7·5
Cape Town, Cape of Good Hope.	33 56·1 S.	18 28·7 E.	D = + 14·63 + 15·00 sin (0·610m + 77·7)	—2·0	—2·5

Compared with similar expressions for stations on our Atlantic seacoast, between Eastport, Me., and Savannah, Ga., the most notable feature of the above stations located in the North and South Atlantic is the widely enlarged *secular* motion, both in range and in period. The average range for our Atlantic coast stations is about twice 3°, whereas the average range for stations in the Azores, Cape Verde, St. Helena,* at Rio de Janeiro, and at Cape Town is twice 13½°, or 4½ times as great. Again, for our coast stations α equals about 1·350; for the five Atlantic stations α equals, on the average, 0·674; in other words, for our coast the period of a complete angular swing would be 267 years; whereas for the islands and the coast stations in South America and Africa the period demanded is 534 years on the average, or just (accidentally so) twice as long. This change in the character of the secular motion, as depending on geographical position, is very significant. Though its meaning is at present shrouded in mystery, it may turn out to be an interference phenomenon due to several causes. It will also be noticed that Mr. Preston's observations, falling in a time not very remote from the western extreme of the secular motion, will greatly assist in defining the extreme magnitudes of the declinations for that epoch.

With respect to early observations of the *dip* at our stations, there appears to be but little material in existence; and as to observations for horizontal or total intensity, there are but a very few, as might have been expected from the circumstance that in the first third of this century it was not known how to express either in absolute measure.

The collected dips are given below without attempting to define their annual change, for which latter the observations are far too scanty. The discussion of the dip observations at *Washington, D. C.*, will be found in Appendix No. 6, Coast and Geodetic Survey Report for 1885, pages 150–155 and pages 259–264. To this collection we can now add:

Date.	Dip.	Observer.
	°	
1886·5	+70·51	C. A. Schott and E. D. Preston, at magnetic observatory on First street SE.
1887·6	+70·45	J. B. Baylor, at Coast and Geodetic Survey Office station, between New Jersey avenue and South Capitol street.
1888·4	+70·42	J. B. Baylor, same locality.
1889·7	+70·43	E. D. Preston, same locality.

The annual diminution of the dip for 1885 was given as 3′·5. This seems now somewhat too large, but not enough time has elapsed since that date to make it worth while to reconstruct the exponential formula given on page 263 of the Report.

* The Canary Islands may also be added to this group, though not here discussed.

The secular and annual changes of the magnetic force at stations occupied in connection with the Eclipse Expedition, 1889–'90, etc.—Continued.

At *Fayal Island* we have three observations, viz:

Date.	Dip.	Observer.
	° ′	
1775	+71 01	Cook.
1850	+65 53	H. M. S. Rattlesnake.
1889.8	+64 13·8	E. D. Preston, United States Coast and Geodetic Survey.

St. Vincent Island.

Date.	Dip.	Observer.
	° ′	
1841	+48 44	Fishbourne.
1841	+48 56	Trollope.
1842	+45 35	Allen.
1853	+48 33	Trollope.
1876·3	+43 06	H. M. S. Challenger, 42° 52′ when swinging.
1889·9	+42 12·3	E. D. Preston.

For comparison we may add here observed dips at *Porto Praya* ($\varphi = 14° 54'$, $\lambda = 23° 30'$ W.), Cape Verde Islands.

Date.	Dip.	Observer.
	° ′	
1822	+45 26	Sabine.
1826	+45 45	Dumond d'Urville.
1836	+45 46	Fitz Roy.
1840	+45 22	Ross and Crozier.
1843	+44 52	Belcher.

Sierra Leone.

Date.	Dip.	Observer.
	° ′	
1842	+27 18	Allen.
1889.9	+15 24·2	E. D. Preston.

Gold Coast.

Date.	Dip.	Observer.
	° ′	
1841	+11 32	Allen, at Cape Coast Castle.
1889·9	+ 0 35·4	E. D. Preston, at Elmina.

Cape Town.

Date.	Dip.	Observer.
	° ′	
1841	—53 09	At magnetic observatory. The Ency. Brit. (9th ed.), art. Meteorology, gives — 53° 09′·1.
1842	—53 11	At magnetic observatory. The Ency. Brit. (9th ed.), art. Meteorology, gives — 53° 15′·3.
1842	—53 12	Belcher.
1843	—53 19	At magnetic observatory. Ency. Brit. gives — 53° 20′·2.
1844	—53 36	At magnetic observatory; mean of 3 values. Ency. Brit. gives — 53° 29′·4.
1845	—53 32	At magnetic observatory; mean of 4 values. Ency. Brit. gives — 53° 29′·3.
1845	—53 30	Moore.
1846	—53 33	At magnetic observatory.
1847	—53 41	" " "
1848	—53 47	" " "
1849	—53 52	" " "
1850	—53 58	" " "
1851	—54 02	" " "
1857	—54 36	Frigate Novara.
1873·9	—55 56·3	H. M. S. Challenger, at observatory.
1890·1	—57 15·2	E. D. Preston, " "

It would appear that the negative dip at Cape Town, between 1841 and 1851, increased at an annual rate of 5′·3, between 1851 and 1874 at a rate of 5′·0, and between 1874 and 1890 at a rate of 4′·9.

St. Helena.

Date.	Dip.	Observer.
	° ′	
1840	—21 15	At magnetic observatory, Longwood.
1841	—21 26	" " "
1842	—21 25	" " "
1843	—21 45	" " "
1844	—21 56	" " "
1845	—21 55	" " "
1846	—22 14	" " "
1847	—22 37	" " "
1848	—22 49	" " "
1890·1	—31 11·0	E. D. Preston, at Longwood.

Between 1840 and 1848 the annual increase of negative dip was 11′·7, and between 1848 and 1890 it was 11′·9.

The secular and annual changes of the magnetic force at stations occupied in connection with the Eclipse Expedition, 1889–'90, etc.—Continued.

The local disturbances at the island are very prominent; for the anchorage and vicinity of *Jamestown* we have:

Date.	Dip.	Observer.
	° ′	
1839	−17 55	Du Petit Thouars (anchorage).
1840	−18 21	Ross (Sister's Walk).
1842	−17 01	Belcher (Sister's Walk).
1846	−19 23	Smythe (Sister's Walk).
1890·1	−29 39	E. D. Preston, Jamestown.

Between 1839 and 1890 the average annual increase in negative dip was 13′·8 about.

Ascension Island.

Date.	Dip.	Observer.
	° ′	
1834	+ 1 57	Allen.
1836	+ 1 39	Fitz Roy.
1839	+ 0 06	Du Petit Thouars.
1842	− 0 08	Allen.
1863	− 4 47	H. M. S. Hecaté.
1864	− 5 57	Rockeby.
1876·2	− 7 56·1	H. M. S. Challenger at Georgetown.
	− 9 57·2	H. M. S. Challenger at Green Mountain.
1890·2	−11 37·9	E. D. Preston at Georgetown.
	−12 11·7	E. D. Preston at Green Mountain.

At this station the average annual increase of negative dip between 1834 and 1890 has been about 14′·5.

*Barbados.**

Date.	Dip.	Observer.
	° ′	
1890·3	+43 08·2	E. D. Preston, at Bridgeport.

* For observations of 1835, 1836, and 1846 see Appendix No. 6, Report for 1885, page 246.

Bermuda.†

Date.	Dip.	Observer.
	° ′	
1890·4	+64 47·6	E. D. Preston, at Nonsuch Island.

† For early observations (1831 to 1873) see Appendix No. 6, Report for 1885, pages 247, 248.

As a general result we note that at all stations for the present (and for a number of years past) the dip, where positive (north end dipping), is decreasing, or, what is the same, where negative (south end dipping), is increasing.

The magnetic *intensities* given below are all that could be found for the stations visited by Mr. Preston.

The observed and computed values of the horizontal component (H) and for the total amount (F) of the magnetic force at *Washington* will be found in Appendix No. 6, Report for 1885, pages 150–155, 267–271. To this collection we can now add:

Year.	H. in Brit. units.	H. in dynes.	F. in Brit. units.	F. in dynes.	Observers.
1886·5	4·403	0·2030	13·194	0·6084	C. A. Schott and E. D. Preston } At Magnetic Observatory, on First st. SE. Magnetometer No. 7.
1887·5	4·406	0·2031	-----	-----	C. A. Schott
1887·6	4·361	0·2011	13·031	0·6008	J. B. Baylor } At Magnetic station of Office; Magnetometer No. 3.
1888·5	4·359	0·2010	13·006	0·5997	J. B. Baylor
1889·7	4·364	0·2012	13·028	0·6007	E. D. Preston, at Magnetic station of Office; Magnetometer No. 11.

St. Vincent Island.

1876·3	6·262	0·2887	8·577	0·3955	*Challenger* expedition.
1889·9	5·938	0·2738	8·016	0·3696	E. D. Preston, at Porto Grande.

Cape Town.

1842	4·45	0·2053	7·43	0·3426	Belcher.
1844·5	4·46	0·2056	7·51	0·3463	At Magnetic Observatory.
1845	4·46	0·2057	7·50	0·3458	Moore.
1845·5	4·50	0·2077	7·58	0·3495	At Magnetic Observatory.
1857	4·47	0·2059	7·71	0·3555	Austrian frigate *Novara*.
1873·9	4·314	0·1989	7·704	0·3552	*Challenger* expedition.
1890·1	4·155	0·1916	7·682	0·3542	E. D. Preston, at Observatory.

St. Helena.

1840	5·66	0·2612	6·08	0·2803	Ross, at Longwood Observatory.
1840	5·96	0·2749	6·28	0·2896	Crozier, at Sisters Walk.
1840	5·96	0·2749	6·28	0·2896	Ross, at Sisters Walk.
1846	5·93	0·2736	6·29	0·2900	Smythe, at Sisters Walk.
1890·1	5·407	0·2493	6·222	0·2869	E. D. Preston, at Jamestown.
1890·1	4·960	0·2287	5·795	0·2672	E. D. Preston, at Longwood Observatory.

The secular and annual changes of the magnetic force at stations occupied in connection with the Eclipse Expedition, 1889–'90, etc.—Continued.

Ascension Island.

Year.	H. in Brit. units.	H. in dynes.	F. in Brit. units.	F. in dynes.	Observers.
1842	6·61	0·3048	6·61	0·3048	Belcher.
1863	6·06	0·2793	6·08	0·2803	H. M. S. *Hecaté*.
1864	6.29	0·2902	6·33	0·2918	Rockeby.
1876·2	6.075	0·2801	6·133	0·2828	*Challenger* expedition, at Georgetown.
1876·2	6·125	0·2824	6·217	0·2867	*Challenger* expedition, at Green Mountain.
1890·2	5·975	0·2755	6.101	0·2813	E. D. Preston, at Georgetown.
1890·2	5·804	0·2676	5·938	0·2738	E. D. Preston, at Green Mountain.

*Barbados.**

1890·3	6·556	0·3023	8·985	0·4143	E. D. Preston, at Bridgetown.

* For observations earlier than the year 1890, see Appendix No. 6, Report for 1885, pp. 246–247.

Bermuda.†

1890.4	5·060	0.2333	11.881	0.5478	E. D. Preston, at Nonsuch Island.

† For early observations and at various localities, see Appendix No. 6, Report for 1885, pp. 246–249.

We note a systematic decrease, both in the horizontal component and in the total force, between the latest dates at the following places: At Barbados, at the Cape Verde Islands, at Ascension Island, at St. Helena, and at Cape Town.

APPENDIX NO. 4—1891.

RESULTS OF THE OBSERVATIONS RECORDED AT THE U. S. COAST AND GEODETIC SURVEY MAGNETIC OBSERVATORY AT LOS ANGELES, CAL., IN CHARGE SUCCESSIVELY OF MARCUS BAKER, ACTING ASSISTANT, CARLISLE TERRY, JR., SUBASSISTANT, AND RICHARD E. HALTER, ASSISTANT, BETWEEN THE YEARS 1882 AND 1889.

PART III.—RESULTS OF THE DIFFERENTIAL MEASURES OF THE HORIZONTAL INTENSITY.

Discussion and report by CHARLES A. SCHOTT, Assistant.

[Submitted for publication December 31, 1891.]

TABLE OF CONTENTS.

ILLUSTRATIONS.

INTRODUCTORY NOTE.

The general plan and object of these magnetic observations has been explained in the preceding Parts I and II,* and the instruments both for absolute and differential measures have there been described. The present or third part deals with the reduction, analysis, and discussion of the hourly measures of the horizontal force from continuous photographic registration during seven years by an Adie magnetograph. The method of reduction being, *cœteris paribus*, the same as that employed in Part II for the differential measures of the declination, no further exposition of it will here be needed.

THE BIFILAR MAGNETOMETER.

The adjustment of this instrument has remained undisturbed† from the time it was set up to the close of the observations, and its scale value was determined at least once a year. The magnet and ap-

* U. S. Coast and Geodetic Survey Report for 1889–'90, Appendices Nos. 8 and 9.

† Excepting a small change on February 13, 1889.

Results of the differential measures of the horizontal intensity from observations recorded at Los Angeles, Cal.

pendages were suspended by two threads each composed of six single silk fibers. The *scale* is mounted on the reading telescope, and is exactly like the scale of the unifilar magnetometer; it is placed with the zero division towards the north, hence, with the five hundredth (or last) division towards the south, the numbers as seen through the telescope appear erect and increase from left to right.

The magnet is suspended in the magnetic prime vertical with its north (seeking) end to the west, and *increasing* scale readings indicate a movement of the west (or north seeking) end of the magnet towards the north, hence correspond to *increasing* horizontal force.

The suspension thread consists of double, untwisted, raw silk fiber, of six parts; the length is 14·1 inches, or $35{\cdot}81^{cm}$. The distance between the suspension fibers at the upper end is 0·242 of an inch or $0{\cdot}615^{cm}$, and at the pulley of the lower end 0·374 of an inch or $0{\cdot}950^{cm}$.

The torsion head of the bifilar is exactly the same as that of the unifilar in size and graduation.

The angular value (a) of a division of the scale is found as follows: Length of a division of the scale, $l = 0{\cdot}0197$ of an inch or $0{\cdot}05^{cm}$, front edge of rim of scale to mirror, 41·38 inches; or $105{\cdot}105^{cm}$; thickness of rim, 0·065 of an inch or $0{\cdot}165^{cm}$; two-thirds of thickness of mirror, 0·067 of an inch or $0{\cdot}170^{cm}$; hence $r = 105{\cdot}44^{cm}$, which, when multiplied by cos $2\frac{3}{4}^{\circ}$ in consequence of slant measure,* becomes $105{\cdot}32^{cm}$.

$$a = 3437{\cdot}75 \frac{l}{2r} = 0'{\cdot}8160, \text{ which has been adopted.}$$

To determine the corresponding space on the cylinder through which the luminous dot will move, we have given: the distance from recording cylinder to face of mirror, 57·84 inches ($146{\cdot}91^{cm}$) + two-thirds thickness of mirror, 0·067 of an inch ($0{\cdot}170^{cm}$) = $147{\cdot}08^{cm}$; hence, corresponding space on cylinder $= \dfrac{0{\cdot}05 + 147{\cdot}08}{105.32} = 0{\cdot}06982^{cm}$ or 100 scale divisions equal to $6{\cdot}98^{cm}$ measured perpendicularly to the base of the bifilar trace.

SCALE VALUE IN TERMS OF THE HORIZONTAL FORCE.

For determining the value of a scale division in terms of the force, three methods are available; they have all been employed at Los Angeles with closely concurrent results.

First method (*torsion angle*).—By this method we have the scale coefficient k expressed in parts of the horizontal component H of the force given by

$$k = \frac{d\,\mathrm{H}}{\mathrm{H}} = a\,(n' - n) \cot v$$

*Mr. Baker points out that the inclination of the scale to the horizontal plane passing through the center of the mirror should be taken into account in the value of r, in the case of the bifilar as well as of the unifilar. The scale is 2 inches ($5{\cdot}08^{cm}$) above this plane, and the angle is about $2\frac{3}{4}^{\circ}$.

where $a =$ the value of one division of the scale in radians

$$= \frac{0\cdot8160}{3437\cdot75} = 0\cdot00023737$$

n' and $n =$ any two scale readings, and

$v =$ angle of planes of detorsion (in the magnetic prime vertical) and of suspension.

First determination made on September 21, 1882, M. Baker, observer. The bifilar magnet was first suspended in the magnetic meridian and the plane of detorsion likewise was placed, by trial, into the same plane; the torsion head then read 60° 30′. A repetition of this operation on the next day gave 60° 32′·5; the scale read 254·4. The magnet was then removed and a brass weight (to weigh the same as the magnet) inserted in its place; the scale then read 126·0; the difference, 128·4, or its angular value $0\cdot816 \times 128\cdot4 = 1° \ 44'\cdot8$, is the angle between the magnetic meridian and the plane of detorsion; the latter plane lies consequently N. 1° 44′·8 W. from the magnetic meridian. The plane of detorsion when in the magnetic meridian reads, therefore, at the torsion head $60° \ 32'\cdot5 + 1° \ 44'\cdot8 = 62° \ 17'\cdot3$. The bifilar magnet was next put in position with the torsion head to read 267° 00′, hence we have $90° + v = 62° \ 17'\cdot3 + 360° \ 00' - 267° \ 00' = 155° \ 17'\cdot3$ and $v = 65° \ 17'\cdot3$.

Putting $n^1 - n = 1$ for one division, we get

$$k = 0\cdot00023737 \cot 65° \ 17'\cdot3 = 0\cdot0001092.$$

Second method (*by weights*).—By this method we ascertain the change of scale readings by the addition of a given weight, say of $\frac{1}{100}$ part of the combined weight of the magnet, stirrup, pulley, mirror, and $\frac{1}{2}$ suspension. On August 30, 1882, the weight of magnet and appendages was found to be 1 730 grains (112·10 grammes), and the weights of the two small brass weights were actually or ostensibly* the $\frac{1}{100}$ part of this.

The pulley used was the middle-sized one. On September 22, 1882, a set of observations was made with weights alternately *off* and *on*, with the mean effect of a diminution of the scale reading with weight *on* of 91·08 scale divisions; hence

$$k = \frac{0\cdot01}{91\cdot08} = 0\cdot0001098$$

Third method (*by deflections*).—For this a special apparatus is provided. A deflecting magnet D, held horizontally in the magnetic meridian, is placed consecutively at a given convenient distance, and end on to the north and to the south of the middle of the bifilar magnet, and the deflections of the latter are observed; it is next placed horizontally

* The particular pulley referred to is not specified, but the weigher, Mr. J. J. Clark, Office of Standard Weights and Measures, was to use the medium-sized one.—[SCH.]

Results of the differential measures of the horizontal intensity from observations recorded at Los Angeles, Cal.—Continued.

in the magnetic prime vertical, end on to the middle of the unifilar magnet and at the same distance from it, as in the case of the bifilar magnet to the east and west of it, and the deflection of the unifilar magnet is noted. Let n = number of scale divisions which the bifilar is deflected and u = the angle through which the unifilar is deflected, then

$$k = \frac{\tan u}{n}$$

On September 22, 1882, a set of deflections was made at a distance of 1 foot and 11 inches, or $58{\cdot}42^{cm}$, and it was found that $n = 148{\cdot}77$ scale divisions and $u = 68{\cdot}82$ scale divisions $= 68{\cdot}82 \times 0'{\cdot}794 = 54'\ 38''{\cdot}6$; therefore

$$k = \frac{\tan 54'\ 38''{\cdot}6}{148{\cdot}77} = 0{\cdot}0001069$$

RECAPITULATION OF VALUES DETERMINED SEPTEMBER 22, 1882.

First method (torsion)	$k = 0{\cdot}0001092$	mean value, 0·0001086
Second method (weights)	1098	
Third method (deflections)	1069	

It was deemed unnecessary to give in detail the observations for scale values subsequently made; they were all by the method of deflections and at three distances between the extremes, 2·000 and 1·833 feet* (60·96 and $55{\cdot}87^{cm}$), the accord in the results by the several distances is so close that we only present here the mean values.

Synopsis of results for value of one division of scale of the bifilar, expressed in parts of the horizontal force.

Year.	Month and day.	Observer.	k	Remarks.
1882	Sept. 22	M. B.	0·0001086	Mean from 3 methods.
1882	Oct. 31	M. B.	1094	Mean from 2 methods.
1883	Aug. 1	M. B.	1082	3 sets of deflections.
1884	July 22	M. B.	1086	" " " "
1885	July 1	C. T.	1102	" " " "
1886	June 25	C. T.	1089	" " " "
1887	Jan. 4	C. T.	1094	" " " "
1887	June 24	R. E. H.	1099	" " " "
1887	Dec. 29	R. E. H.	1097	" " " "
1888	June 26	R. E. H.	1101	" " " "
1888	Dec. 20	R. E. H.	1098	" " " "
1889	Oct. 1	R. E. H.	1091	" " " "
		Mean	0·0001093 ±1	

* The deflecting magnet pulls the bifilar magnet entirely off the scale at a distance of 1·75 feet.

which value has been adopted. The value of k is practically constant throughout the period of observations, and would also indicate that there was no appreciable loss in the magnetic moment of the bifilar magnet.

The reading of the traces was effected similarly to the method employed for reading the unifilar traces; the hourly tabulation of the readings uncorrected for effect of changes of temperature was made by the respective observers. Interpolations were made by me by the method already indicated, and such values are given within brackets.

DETERMINATION OF THE TEMPERATURE OF THE HORIZONTAL AND VERTICAL FORCE MAGNETS AND METHOD OF REDUCTION OF OBSERVATIONS TO A UNIFORM TEMPERATURE.*

For determining the correction which the tabulated scale readings of the horizontal and vertical force magnets require, the following provisions were made: (1) Under each bell glass near to and parallel with the magnets were placed standard mercurial (centigrade) thermometers and read daily at stated times. (2) In the northwest corner of the magnet room, on a shelf about a meter above the floor, was placed a clock and thermograph, as devised by Mr. Werner Suess, mechanician to the Survey, for continuous automatic record of the temperature of the room.† This arrangement consists in a device whereby a needle point is moved with variations of temperature, and depending upon the inequality in the coefficients of expansion of zinc and glass, along the surface of a revolving cylinder, around which is wrapped a sheet of soft paper. Every half hour the clock automatically closes a circuit acting upon an electromagnet, by means of which the needle point is made to prick a hole in the paper. With unvarying temperature these holes are found in a straight line, but with varying temperature they form curves, the amplitudes of which are proportional to the variations of temperature. The clock was placed in position in October, 1882, and regular observations commenced November 5, 1882. From an inspection of the curves produced it became evident that the magnet room was coldest at about 8 a. m. and warmest at about 5 p. m. On February 1, 1883, systematic observations of the temperatures indicated by the thermometers under the bell glasses at about these hours of the day were commenced, thus furnishing complete data for the temperature corrections. After reaching Washington in September, 1884, Mr. Baker, with the aid of Mr. J. W. G. Atkins, set to work to tabulate the thermograms and to deduce the mean daily and hourly temperatures of the magnets. From several measures by himself and Mr. Terry it was found that on the time scale (a German silver ruler) 4·648 inches

*This paragraph is taken from Mr. Baker's record with but slight modification.

†A description and drawing of the instrument is on file in the Office, *vide* Mr. Suess's report of January 7, 1883, to the Superintendent, on the mounting and adjusting of the Adie magnetograph at Los Angeles.

Results of the differential measures of the horizontal intensity from observations recorded at Los Angeles, Cal.—Continued.

or 11·81 cm. represented 24 hours. The ordinate scale consists of a triangle of German silver graduated into equal (but arbitrary) spaces. This unit space was $\frac{1}{8}$ of an inch (.3175 cm.), and it was subdivided in halves. The numbers, each of $\frac{1}{16}$ of an inch, range from 7 at the base to 36 at the top of the triangle, and in reading the fifteenth line of the scale was made to coincide with the base line on the thermogram. With this arrangement *increasing* numbers correspond to *diminishing* temperatures. Tenths of divisions were estimated.

To determine the mean daily and mean hourly temperatures of the force magnets from this tabulation the observer proceeded as follows:

Let $s_1\ s_2\ s_3 \ldots\ldots s_{24}$ be the scale readings at the hours 1, 2, 3......24 and s_m the mean scale reading of the day $= \frac{1}{24}(s_1 + s_2 + s_3 + \ldots\ldots s_{24})$; let $t_1\ t_2\ t_3 \ldots\ldots t_{24}$ be the temperature of the bifilar (or vertical force) magnet at the hours 1, 2, 3......24 and t_m the mean daily temperature or $\frac{1}{24}(t_1 + t_2 + t_3 + \ldots\ldots t_{24})$, of which t_8 and t_{17} are the only values observed; then, assuming the variations of the scale readings to be proportional to the changes of temperature, we have

$$(t_m - t_8) : (t_{17} - t_8) = (s_m - s_8) : (s_{17} - s_8)$$

whence
$$t_m = t_8 + (t_{17} - t_8)\,\frac{s_m - s_8}{s_{17} - s_8}$$

in degrees centigrade.

From this formula the mean daily temperatures of the force magnets may be computed.

To determine the mean *hourly temperature for each month*, let $S_1\ S_2\ S_3 \ldots\ldots$ be the mean scale readings for a month at the respective hours, and S_h the general symbol for any hour; also let $T_1\ T_2\ T_3 \ldots\ldots$ be the mean temperatures for a month of the bifilar (or vertical force) magnet at the respective hours and T_h the general symbol for any hour; then, as before,

$$T_h = T_8 + (S_h - S_8)\,\frac{T_{17} - T_8}{S_{17} - S_8}$$

where $\dfrac{T_{17} - T_8}{S_{17} - S_8}$ is constant for any one month.

The hourly tabulation of the thermograph and the bi-daily readings of the bell-glass thermometers were continued up to May 10, 1885, when the thermograph was discontinued in consideration of the fact that the daily range of the temperature of the magnets was quite small and the law of its hourly variation well understood.

As it would serve no particular purpose to encumber this report with the hourly record of the temperature of the magnet, it will suffice to present here a table showing the diurnal variation of the temperature of the magnet for the monthly averages. The table was taken from the observer's computation.

Abstract of mean hourly temperature of the bifilar magnet.

[In degrees centigrade.]

1883.

Local hours.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
		°	°	°	°	°	°	°	°	°	°	°
1	------	18.55	21.71	21.12	23.36	26.90	28.77	29.02	30.28	25.33	23.17	21.99
2		18.40	21.62	20.98	23.28	26.79	28.65	28.87	30.18	25.24	23.03	21.84
3		18.26	21.55	20.88	23.20	26.70	28.57	28.75	30.06	25.18	22.93	21.74
4		18.15	21.46	20.81	23.16	26.61	28.49	28.65	29.97	25.13	22.85	21.62
5		18.06	21.40	20.71	23.09	26.54	28.42	28.55	29.90	25.09	22.76	21.52
6		17.98	21.32	20.62	23.07	26.47	28.37	28.45	29.83	25.07	22.67	21.42
7	------	17.90	21.28	20.56	23.06	26.45	28.34	28.42	29.79	25.07	22.61	21.31
8		17.86	21.27	20.58	23.16	26.56	28.36	28.47	29.77	25.10	22.56	21.22
9		17.91	21.33	20.72	23.31	26.75	28.44	28.62	29.85	25.21	22.57	21.19
10		18.19	21.51	20.98	23.55	27.12	28.69	28.97	30.02	25.39	22.77	21.30
11		18.35	21.57	21.09	23.63	27.21	28.81	29.18	30.14	25.48	22.92	21.45
Noon.	------	18.65	21.67	21.25	23.76	27.32	29.02	29.45	30.35	25.63	23.14	21.71
13	------	18.90	21.82	21.45	23.89	27.49	29.28	29.71	30.63	25.79	23.45	21.99
14		19.15	22.01	21.64	23.99	27.65	29.51	29.99	30.85	25.92	23.75	22.23
15		19.36	22.16	21.75	24.03	27.74	29.64	30.17	31.02	26.02	23.97	22.48
16		19.52	22.28	21.86	24.11	27.82	29.74	30.26	31.15	26.08	24.15	22.65
17		19.63	22.33	21.92	24.13	27.89	29.80	30.34	31.25	26.14	24.29	22.80
18		19.68	22.36	21.99	24.15	27.99	29.83	30.40	31.33	26.22	24.35	22.84
19	------	19.64	22.32	21.97	24.13	28.03	29.85	30.40	31.29	26.15	24.25	22.77
20		19.51	22.23	21.89	24.03	27.95	29.75	30.26	31.13	26.00	24.08	22.62
21		19.36	22.11	21.75	23.92	27.78	29.53	30.01	30.89	25.81	23.89	22.46
22		19.17	21.99	21.59	23.76	27.59	29.29	29.74	30.66	25.63	23.68	22.30
23		18.99	21.87	21.44	23.62	27.40	29.07	29.53	30.48	25.49	23.46	22.12
Midn't.		18.80	21.75	21.27	23.48	27.23	28.90	29.31	30.30	25.34	23.29	21.97
Means.	------	18.75	21.79	21.28	23.62	27.25	29.05	29.40	30.46	25.56	23.36	21.98

Results of the differential measures of the horizontal intensity from observations recorded at Los Angeles, Cal.—Continued.

Abstract of mean hourly temperature of the bifilar magnet.

[In degrees centigrade.]

1884.

Local hours.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
	°	°	°	°	°	°	°	°	°	°	°	°
1	20·08	20·54	20·89	21·02	23·08	25·69	28·37	29·40	27·26	24·86	23·33	21·08
2	19·93	20·45	20·78	20·93	23·00	25·60	28·24	29·29	27·11	24·75	23·22	20·99
3	19·80	20·42	20·67	20·87	22·96	25·51	28·16	29·17	27·00	24·65	23·13	20·91
4	19·70	20·34	20·61	20·79	22·92	25·43	28·05	29·12	26·91	24·55	23·06	20·83
5	19·64	20·27	20·53	20·72	22·87	25·37	27·95	29·01	26·85	24·44	22·98	20·74
6	19·57	20·21	20·47	20·68	22·85	25·31	27·86	28·93	26·80	24·32	22·91	20·65
7	19·49	20·14	20·40	20·63	22·84	25·28	27·81	28·86	26·75	24·24	22·84	20·57
8	19·42	20·08	20·41	20·67	22·88	25·34	27·85	28·89	26·76	24·19	22·81	20·51
9	19·43	20·10	20·44	20·96	23·17	25·73	28·16	29·23	26·93	24·35	22·92	20·52
10	19·57	20·18	20·68	21·45	23·32	25·76	28·25	29·29	27·05	24·47	23·04	20·68
11	19·65	20·27	20·76	21·45	23·34	25·84	28·37	29·41	27·22	24·65	23·24	20·87
Noon.	19·88	20·43	20·89	21·46	23·40	25·95	28·56	29·57	27·41	24·89	23·50	20·84
13	20·14	20·61	20·99	21·55	23·50	26·03	28·72	29·74	27·58	25·11	23·80	21·05
14	20·43	20·82	21·11	21·64	23·61	26·11	28·91	29·93	27·75	25·31	24·13	21·26
15	20·67	21·00	21·18	21·71	23·69	26·16	29·05	30·05	27·87	25·47	24·35	21·45
16	20·90	21·18	21·25	21·76	23·77	26·22	29·14	30·17	28·00	25·60	24·55	21·62
17	21·11	21·29	21·30	21·84	23·85	26·29	29·25	30·22	28·11	25·71	24·66	21·74
18	21·24	21·40	21·38	22·00	23·95	26·40	29·38	30·29	28·17	25·79	24·75	21·87
19	21·18	21·36	21·38	21·93	23·90	26·39	29·35	30·25	28·15	25·75	24·62	21·81
20	21·01	21·23	21·31	21·81	23·80	26·33	29·25	30·17	28·03	25·60	24·37	21·64
21	20·77	21·07	21·21	21·64	23·68	26·24	29·08	30·06	27·88	25·43	24·10	21·47
22	20·59	20·94	21·08	21·47	23·56	26·10	28·90	29·89	27·69	25·23	23·84	21·30
23	20·43	20·80	20·95	21·33	23·43	25·97	28·72	29·73	27·51	25·06	23·65	21·14
Midn't.	20·27	20·68	20·82	21·23	23·31	25·86	28·50	29·58	27·35	24·90	23·50	21·01
Means.	20·20	20·66	20·89	21·31	23·36	25·87	28·58	29·59	27·42	24·97	23·64	21·10

Abstract of mean hourly temperature of the bifilar magnet.

1885.

Local hours.	Jan.	Feb.	March.	April.	Local hours.	Jan.	Feb.	March.	April.
	°	°	°	°		°	°	°	°
1	20·60	22·14	23·94	24·90	13	20·73	22·29	24·47	25·17
2	20·45	21·97	23·83	24·78	14	21·07	22·61	24·72	25·26
3	20·37	21·87	23·75	24·68	15	21·34	22·89	24·84	25·31
4	20·28	21·79	23·64	24·60	16	21·53	23·07	24·93	25·38
5	20·21	21·71	23·59	24·53	17	21·70	23·27	25·02	25·41
6	20·14	21·59	23·53	24·48	18	21·83	23·44	25·16	25·45
7	20·04	21·48	23·48	24·42	19	21·77	23·42	25·15	25·45
8	19·95	21·41	23·49	24·41	20	21·56	23·24	24·99	25·42
9	19·95	21·37	23·67	24·60	21	21·33	23·02	24·77	25·35
10	19·99	21·48	23·80	24·73	22	21·13	22·76	24·58	25·22
11	20·17	21·70	23·96	24·91	23	20·97	22·55	24·37	25·12
Noon.	20·42	21·98	24·21	25·03	Midnight	20·79	22·35	24·20	25·01
					Means.	20·76	22·31	24·25	24·98

The average daily range of the temperature of the magnet is as follows:

	°		°
In January,	1·85 C.	In July,	1·54 C.
February,	1·74	August,	1·70
March,	1·25	September,	1·49
April,	1·28	October,	1·38
May,	1·10	November,	1·86
June,	1·35	December,	1·50

Average daily range during the year, 1°·50 C., which small variation is, in a great measure, due to the equable climate of the place and the protection afforded by the double walls of the observatory. The difference of the mean temperatures of the warmest and coldest month is likewise small, viz, 9°·2 C., on the average during seven years.

Temperature coefficient of the bifilar magnet.—The effect of a change of temperature of the magnet on its magnetic moment was determined in two ways: First, by direct observations, alternately heating and cooling the magnet; and, secondly, by extracting from the differential series of observations themselves the required temperature correction.

(*a*) The direct observations of September 7 and 11, 1882, by means of deflections were made in accordance with "Directions for measurement of terrestrial magnetism," Appendix No. 8, Coast and Geodetic Survey Report for 1881, pages 155, 156. The bifilar magnet was placed south end eastward in a copper box on deflecting bar 2 feet east of the unifilar magnet, and then alternately heated and cooled by means of warm water and ice. Special readings for changes of declination during these observations were made with Magnetometer No. 8, but these subsequently proved anomalous,* and the average diurnal law of change during October was substituted in their place, retaining only the first and last readings.

* Supposed due to the development of torsion in the suspension while the temperature of the air was rapidly changing.—SCH.

Results of the differential measures of the horizontal intensity from observations recorded at Los Angeles, Cal.—Continued.

The results, however, did not prove satisfactory, as may be seen from the observations of September 7, viz:

Observations for temperature coefficient, $q = \dfrac{a\,n \cot u}{t - t_0}$ *of the horizontal force magnet September 7, 1882.*

[Observers: Baker and Suess.]

Local time.	No.	Read. of Unif. Mag.	Corr'n for diurnal change.	Corr'd reading U. Mag.	Temp. (Fahr.).
h. m.		*d.*	*d.*	*d.*	°
11 00		326·0	+0·1	326·1	
12 00	1	127·1	+1·6	128·7	35·8
33	2	127·4	+1·7	129·1	49·5
50	3	128·0	+1·8	129·8	53·0
13 05	4	128·5	+1·8	130·3	65·8
24	5	128·8	+1·6	130·4	71·5
40	6	129·7	+1·3	131·0	79·0
50	7	130·2	+1·1	131·3	89·5
14 06	8	130·4	+0·8	131·2	81·0
22	9	130·4	+0·6	131·0	70·4
36	10	130·2	+0·2	130·4	60·8
50	11	130·4	—0·1	130·3	54·3
15 05	12	130·6	—0·4	130·2	49·0
35	13	129·8	—1·2	128·6	33·0
16 15		328·1	—2·0	326·1	

Combination.	U. M. reading (mean).	Temp. (Fahr.).	n	$t-t_0$ (Fahr.).
	d.	°	*d.*	°
1 and 13	128·65	34·40	+1·61	+28·61
2 12	129·65	49·25	+0·61	+13·76
3 11	130·05	53·65	+0·21	+ 9·36
4 10	130·35	63·30	—0·09	— 0·29
5 9	130·70	70·95	—0·44	— 7·94
6 8	131·10	80·00	—0·84	—16·99
7	131·30	89·50	—1·04	—26·49
Means.	130·26	63·01	Σ† 4·84	Σ† 103·44 = 57°·47 C.

† All values of n and of $t - t_0$ being taken positive.

$u = 0'{\cdot}794\ (326{\cdot}1^d - 130{\cdot}26^d) = 2°\ 35'{\cdot}5$

$a = 0{\cdot}794/3437{\cdot}75 = 0{\cdot}000231$

$\therefore q = 0{\cdot}000430$

and $\dfrac{q}{k} = 3{\cdot}95$ scale divisions of the horizontal force instrument.

This value is rather large, and the observations of September 11 give a still larger value for q/k, nearly 7 scale divisions; neither set was satisfactory to the observer, hence we have recourse to the method—

(*b*) Determination of the value of q from the differential observations themselves. This is the better method, as it takes in all circumstances attending changes of temperature and, in particular, changes in suspension of magnet. For this purpose the series from February, 1883, to April, 1885, was selected as the interval for which the temperature of the magnet was best known. The photographic traces were then examined and the dates noted when the traces were smooth and apparently normal. The daily mean temperature (t_m) corresponding to these quiet days and their daily mean scale readings (s_m) were tabulated for each month, and a value for q deduced as follows: The monthly data were arranged in two groups, one of days with mean temperature above, the other with mean temperature below the average; for each group the mean temperature (t) and the mean scale readings (s) were taken; hence, $q = \frac{\Delta s}{\Delta t}$ in scale divisions, for 1° C. The following example will show the process:

OCTOBER, 1883.

Date.	s_m	t_m	Group.	Date.	s_m	t_m	Group.
	d.	°			*d.*	°	
1	315·03	28·49	I	23	318·32	26·81	I
2	316·04	26·76	I	24	321·00	26·46	I
3	319·38	27·07	I	27	325·70	24·00	II
7	322·38	24·82	II	28	329·00	23·42	II
8	322·38	25·14	II	29	328·32	24·45	II
9	321·73	25·73	I	30	323·38	25·58	II
10	322·10	25·78	I	31	324·40	25·31	II
11	321·59	26·04	I				
21	319·43	25.22	II		Mean.	25·66	
22	319·75	25·14	II				

	d.	°
For Group I we have	s=319·40 and	t=26·64 C.
For Group II we have	323·86	24·79
	$\triangle s$= 4·46	$\triangle t$= 1·85
	hence q= 2·41 divisions.	

The number of quiet days in a month vary from 8 to 19; but two months, June and July, 1883, failed to give admissible values for q, viz, 5·5 and 4·7, which are abnormally large and were rejected.

Recapitulation of resulting values for q.

	d.		*d.*		*d.*		*d.*		*d.*
Feb. 1883,	2·57	Sept.	2·93	Feb.	3·09	July	2·00	Dec.	2·04
Mar.	2·86	Oct.	2·41	Mar.	2·57	Aug.	2·31	Jan. 1885,	1·71
Apr.	3·41	Nov.	2·81	Apr.	1·73	Sept.	1·75	Feb.	1·66
May	3·00	Dec.	3·00	May	1·67	Oct.	2·34	Mar.	2·68
Aug.	1·37	Jan. 1884,	2·47	June	3·13	Nov.	3·73	Apr.	2·70

Results of the differential measures of the horizontal intensity from observations recorded at Los Angeles, Cal.—Continued.

Mean of 25 values $q=2{\cdot}48\pm0{\cdot}08$ scale divisions, which value has been adopted; it is equal to $0{\cdot}000\,269\pm{\cdot}000\,009$ part of the horizontal force.*

The next step in the reduction consisted in the application of a correction to each hourly scale reading for difference in temperature of the bifilar magnet from an adopted mean or standard temperature T_0, for which we take 23°·6 C., as derived from the monthly mean values for temperature of the intensity magnets during seven years and given in the following table:

Monthly mean values of the temperature of the bifilar and the balance magnets derived from the readings of the thermometers under the bell glasses of the magnetometers, 1882–'89.

Month.	Bif.	Bal.	Diff.	Month.	Bif.	Bal.	Diff.
	°	°	°		°	°	°
October.	25·4	24·7	0·7	April.	22·2	21·6	0·6
November.	22·9	22·2	0·7	May.	23·6	22·9	0·7
December.	21·2	20·6	0·6	June.	26·0	25·3	0·7
January.	19·6	18·9	0·7	July.	28·1	27·3	0·8
February.	20·1	19·4	0·7	August.	28·8	28·0	0·8
March.	21·2	20·5	0·7	September.	28·4	27·6	0·8

Average annual temperature of bifilar magnetometer	23°·96 C.
Average annual temperature of balance magnetometer	23·25
Mean, T_0	23·06 C.

The constant difference (0°·7) between the temperatures of the magnets is due to the circumstance that the bell glass of the bifilar instrument was high and received more heat from radiation of the lamps than the low glass cover of the balance magnetometer.

To reduce the scale reading (s) corresponding to a temperature (t) of the magnet to what it would be if the magnet were at the standard temperature T_0, we have, accordingly, the correction, $\varDelta s = 2{\cdot}48\,(t - T_0)$, which correction has been applied to the tabular hourly readings for the whole seven-year series.

This important but laborious work was entrusted to Mr. L. A. Bauer, and such aid given him as could be had at the time. A full account of

*After the instrument had been transferred to San Antonio, Tex., Assistant A. Braid made two sets of direct observations for q by means of deflections and with readings of a unifilar magnet. February 19, 1890, from 11 readings, extending over 6 hours, and temperature changes of the bifilar magnet between 2° and 50° C., he found $q=0{\cdot}000\,193$; again, on February 24, 1890, from 21 readings during 8 hours and with temperatures varying from 0°·5 to 41° C., he found $q=0{\cdot}000\,240$ part of the horizontal force. This would indicate that our adopted value is within the limits of uncertainty incidental to direct observation.

the detail of this process will be found in the footnote*, and appears over his own signature.

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* *Reduction of bifilar scale-readings to standard temperature, 23°·6 C.*—We have from above, the correction:

$$\triangle s = 2{\cdot}48\,(t - T_0) \qquad . \qquad . \qquad . \qquad (1)$$

As the hourly thermogram-readings tabulated by the observer are not given in degrees centigrade but in arbitrary scale-divisions, it was found most convenient to express $T_0 = 23°{\cdot}6$ C., as nearly as could be, in thermogram scale-divisions and adapt formula (1) accordingly.

Let m = value of one thermogram scale-division in degrees centigrade, $s_1'\ s_2'\ s_3' \ldots s'_{24}$, the hourly thermogram scale-readings, and $S_0' = T_0$ expressed in thermogram scale-divisions, then we have $t = ms'$ and $T_0 = mS_0'$, substituting which in equation (1) there results:

$$\triangle s = 2{\cdot}48m\,(s' - S_0') \qquad . \qquad . \qquad . \qquad (2)$$

To find m and S_0' we proceed as follows:

If t_8 and t_{17} be the readings of the centigrade thermometer under the bifilar bell-glass at the hours of 8 and 17, s'_8 and s'_{17}, the corresponding thermogram scale-readings, and assuming that the variations of the thermogram readings are proportional to the changes in temperature of the magnet, we have:

$$T_0 - t_8 : t_{17} - t_8 :: S_0' - s_8' : s'_{17} - s_8'$$

or

$$S_0' = s_8' + (T_0 - t_8)\,\frac{s'_{17} - s'_8}{t_{17} - t_8}$$

and as

$$m = \frac{t_{17} - t_8}{s'_{17} - s'_8}$$

$$S_0' = s'_8 + \frac{1}{m}\,(23°{\cdot}6 - t_8) \qquad . \qquad . \qquad . \qquad (3)$$

For every day on which the thermograph was operated and readings of the thermometer under the bell-glass taken, we shall have one value of m and one of S_0'. This was done from February 1, 1883, to May 9, 1885, inclusive, or 828 days (one day having been missed, viz: February 14, 1884). Only the mean monthly values were computed, however, as it was found that the daily values were subject to considerable variation, chiefly due to variability of base line of thermogram, necessitating a small daily correction to any mean value of m and S_0' that might be adopted; hence, only approximate values were wanted.

The mean monthly values are:

Month.	m	S_0'	Month.	m	S_0'	Month.	m	S_0'
1883	°	d	1883	°	d	1884	°	d
Jan.	....	....	Nov.	—0·76	18·2	Aug.	+0·76	11·1
Feb.	—0·65	17·5	Dec.	·67	17·9	Sept.	·68	10·7
			1884					
Mar.	·69	18·7	Jan.	·74	17·7	Oct.	·71	10·9
Apr.	·71	18·3	Feb.	·78	18·0	Nov.	·69	11·2
May	·76	18·7	Mar.	·75	18·3	Dec.	·74	11·5
						1885		
June	·76	19·0	Apr.	·68	17·8	Jan.	·73	11·6
July	·83	18·7	May	·67	18·0	Feb.	·76	11·6
Aug.	·79	19·0	June	·68	18·5	Mar.	·73	11·4
Sept.	·77	19·3	July	·67	19·6	Apr.	·74	11·1
Oct.	·75	18·9				May	·79	11·1
				Mean.	18·4		0·73 [Of all.]	11·2

From February, 1883, to July, 1884, inclusive, *decreasing* scale-readings corresponded to *increasing* temperatures, but in August, 1884, the base line was changed so that *increasing* scale-readings corresponded to *increasing* temperatures.

Results of the differential measures of the horizontal intensity from observations recorded at Los Angeles, Cal.—Continued.

We adopt then:

	$m_{\circ}$	S_0'
		d
February, 1883–July, 1884 . . .	−0·73	18·4
August, 1884–May, 1885 . . .	+0·73	11·2

Substituting these values in equation (2), we get:

$$\left.\begin{array}{ll} \text{Feb., 1883–July, 1884} & \triangle S = -2{\cdot}48 \times 0{\cdot}73\,(s' - 18{\cdot}4) = -1{\cdot}8\,(s' - 18{\cdot}4) \\ \text{Aug., 1884–May, 1885} & \triangle S = 2{\cdot}48 + \times\, 0{\cdot}73\,(s' - 11{\cdot}2) = +1{\cdot}8\,(s' - 11{\cdot}2) \end{array}\right\} \ldots(4)$$

The correction obtained from these equations constitutes the primary temperature correction to which a small secondary correction has to be applied, due to variability of base line of thermogram and to reduction of temperature of thermograph, or room, to that of the bifilar magnet. This secondary correction is obtained by noting the differences in the corrections at 8^h and 17^h, as derived from above formulæ and as derived from the absolute temperature-readings at these hours and distributing these differences uniformly over the interval. This secondary correction may amount to 3 bifilar scale-divisions, but is generally less than 2 (on the average about 1), whereas the primary may amount to 20; the average total correction for the seven years is about ± 6. Conveniently arranged tables were then constructed and the *temperature correction supplied in this way from February, 1883, to May 9, 1885.* For 8^h and 17^h the corrections were obtained from the absolute temperature readings. For this portion of the work the data for supplying the temperature correction were best known, and hence these two years form the strongest part of the series. On May 10, 1885, the thermograph was discontinued and only the temperatures of the thermometers under the bell-glasses at 8^h and 17^h were observed, these being very nearly the hours of minimum and maximum temperatures.

Method of supplying temperature correction from May 10, 1885, to September, 1889.—From a discussion of the complete series of hourly temperature corrections for the two years beginning with February, 1883, and ending February, 1885, the following tables were drawn up:

Diurnal variation of temperature correction.

[Expressed in bifilar scale-divisions, one division being equal to 0.000109 in parts of H. A plus sign indicates greater, a minus sign less temperature than mean of day.]

Hour.	Feb., 1883, to Feb., 1884.	Feb., 1884, to Feb., 1885.	Mean of 2 years.	Mean. Summer months. Apr. to Sept.	Mean. Winter months. Oct. to Mar.	Hour.	Feb., 1883, to Feb., 1884.	Feb., 1884, to Feb., 1885.	Mean of 2 years.	Mean. Summer months. Apr. to Sept.	Mean. Winter months. Oct. to Mar.
1^h	−0·56	−0·42	−0·49	−0·66	−0·32	13^h	+0·38	+0·27	+0·32	+0·52	+0·13
2	−0·82	−0·68	−0·75	−0·87	−0·63	14	+0·92	+0·69	+0·81	+0·90	+0·72
3	−1·04	−0·92	−0·98	−1·11	−0·85	15	+1·31	+1·06	+1·18	+1·18	+1·18
4	−1·18	−1·08	−1·13	−1·21	−1·05	16	+1·62	+1·36	+1·49	+1·39	+1·58
5	−1·45	−1·29	−1·37	−1·47	−1·26	17	+1·86	+1·60	+1·73	+1·60	+1·86
6	−1·62	−1·47	−1·54	−1·64	−1·44	18	+2·02	+1·86	+1·94	+1·81	+2·07
7	−1·69	−1·62	−1·65	−1·72	−1·58	19	+1·92	+1·73	+1·82	+1·76	+1·89
8	−1·72	−1·64	−1·68	−1·63	−1·73	20	+1·64	+1·41	+1·53	+1·52	+1·54
9	−1·52	−1·17	−1·35	−1·09	−1·61	21	+1·16	+1·02	+1·09	+1·08	+1·09
10	−0·95	−0·85	−0·90	−0·55	−1·25	22	+0·69	+0·62	+0·66	+0·63	+0·68
11	−0·68	−0·58	−0·63	−0·32	−0·94	23	+0·25	+0·22	+0·24	+0·22	+0·25
Noon	−0·18	−0·17	−0·18	+0·06	−0·41	Midn't	−0·18	−0·12	−0·15	−0·18	−0·12

Hours of minimum and maximum temperatures for the various months.

Month.	Minimum.			Maximum.		
	1883.	1884.	1885.	1883.	1884.	1885.
	h.	*h.*	*h.*	*h.*	*h.*	*h.*
Jan.	–	8	8	–	18	18
Feb.	8	8	9	18	18	18
Mar.	8	7	7	18	18	18
Apr.	7	7	8	18	18	18·5
May	7	7	–	18	18	–
June	7	7	–	19	18·5	–
July	7	7	–	19	18·5	–
Aug.	7	7	–	18	18	–
Sept.	8	7	–	18	18·5	–
Oct.	7	8	–	18	18	–
Nov.	8	8	–	18	18	–
Dec.	9	8	–	18	18	–

From the foregoing tables and curves constructed from them we learn the following:

1. The *minimum temperature* of day occurs at about 7^h 30^m a. m., on the yearly average, happening about half an hour earlier in summer and half an hour later in winter.

2. The *maximum temperature* occurs at about 6 p. m. both in winter and summer, and is about $0^\circ \cdot 1$ C. higher than at 17^h, as recorded by observer.

3. The temperatures at 17^h and 19^h are very nearly the same.

4. The law of change between 8^h and 17^h can be taken as a linear one, the mean of these hours occurring at about 12^h 30^m.

5. The mean of 17^h and 8^h (of next day) occurs at about 23.5^h, the law of change between the time of this mean and 19^h and 7^h (of next day) being very nearly a linear one.

The above deductions were utilized as nearly as could be in supplying the temperature corrections at all hours other than 8^h and 17^h, which, as before, were derived from the absolute temperature readings.

Temperature correction for October, 1882, to February, 1883.—These four months required special treatment, and could not be handled until after the discussion of the complete two-year series of hourly temperature corrections, as given above. As they form the beginning of the seven-year series, the data for supplying the temperature correction were, necessarily, more or less incomplete.

For October the absolute temperature reading of the magnet was taken once a day, and occasionally twice, giving one or two corrections every day. The diurnal law of change, as determined from the months of October, 1883 and 1884, was then applied differentially to the solitary correction. Similarly the first four days in November had to be treated. On November 5, 11 a. m., the thermogram readings began and a solitary reading of the thermometer under the bell glass taken, generally at 9 a. m. Occasionally, however, two readings were taken. From this day to February 1, 1883, the method, as explained in the first part of this paper, was followed. These four months constitute the weakest part of the series.

The temperature corrections obtained by me, as explained in the preceding remarks, were applied to the observer's tabulated bifilar scale readings, and a new copy furnished by Mr. W. C. Maupin, of the computing division. The revision of his work

Results of the differential measures of the horizontal intensity from observations recorded at Los Angeles, Cal.—Continued.

and the furnishing of the monthly hourly means was intrusted to Messrs. James Page and J. B. Boutelle, both of the computing division. The daily and monthly means were supplied with the aid of a comptometer.

An approximate check upon the work was obtained by a comparison of the monthly hourly means with the observer's, approximately corrected for temperature. The close agreement of the two monthly means derived from the hourly and from the daily means served as a further check against gross errors.—[L. A. Bauer, April 1, 1891.

MAGNETIC OBSERVATORY OF THE COAST

Differential observations of the horizontal

[Recapitulation of mean hourly values of reduced scale-readings for magnet at normal temperature horizontal force. Increasing scale

Year.	Month.	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	Noon
1882.	Oct.*	130·3	130·5	131·0	131·9	131·8	131·1	129·6	127·9	125·9	125·4	124·2	125·1
	Nov.	122·5	122·3	124·2	121·9	123·4	123·0	121·8	119·1	116·8	114·1	112·8	115·2
	Dec.	129·9	130·2	131·2	131·3	131·9	132·4	133·6	133·9	133·2	130·2	126·4	125·2
1883.	Jan.	135·1	135·0	135·8	136·4	136·6	137·3	137·6	136·6	135·4	131·5	127·6	128·4
	Feb.	134·4	134·2	135·0	135·6	136·2	136·9	137·4	136·3	135·3	131·9	131·0	130·7
	Mar.	136·3	137·0	137·6	138·2	138·4	138·4	137·2	136·3	135·3	135·0	134·0	133·2
	Apr.	142·2	141·6	141·1	141·6	141·3	141·2	140·8	138·6	136·4	135·2	135·2	135·8
	May	143·5	143·3	143·3	143·2	143·9	144·2	143·2	140·5	140·4	141·6	141·9	143·1
	June	143·2	144·3	142·8	143·3	143·3	143·1	141·1	139·1	139·0	141·4	143·2	143·7
	July	138·5	138·2	137·8	138·2	138·6	139·1	137·7	136·2	134·8	135·6	136·4	136·8
	Aug.	139·8	140·6	140·5	140·5	140·3	140·7	138·2	134·6	134·7	136·0	136·4	136·8
	Sept.	131·5	131·7	131·7	132·8	132·2	133·1	130·1	126·8	125·8	126·1	126·2	127·2
	Oct.	126·9	127·4	128·3	128·5	128·3	127·6	125·4	121·3	120·1	119·9	120·1	120·8
	Nov.	121·0	121·7	122·3	124·0	124·2	123·6	123·3	121·1	118·8	116·7	116·3	117·9
	Dec.	119·6	120·2	121·3	121·5	122·5	123·3	123·5	122·3	120·3	116·5	113·7	113·4
1884.	Jan.	121·0	122·4	122·8	122·5	123·5	123·8	124·0	123·1	120·1	115·1	110·8	111·6
	Feb.	122·9	123·3	124·2	124·8	125·1	125·6	126·7	127·7	127·2	124·8	120·7	117·2
	Mar.	124·1	125·6	125·6	126·1	125·6	125·9	125·0	122·3	119·3	118·9	118·7	118·6
	Apr.	128·1	128·2	129·3	129·5	129·2	129·8	127·1	125·7	124·9	125·0	123·2	123·1
	May	133·1	133·2	132·6	132·5	133·2	133·2	131·9	130·6	131·6	133·0	132·7	132·5
	June	130·8	131·9	131·5	132·1	132·3	132·9	131·6	130·9	131·0	132·1	131·8	132·7
	July	126·4	127·3	127·2	127·6	128·2	128·2	126·6	124·1	124·5	126·0	127·5	128·5
	Aug.	126·9	126·2	126·8	127·0	126·8	126·4	123·8	121·2	122·0	122·1	122·1	123·0
	Sept.	120·7	120·4	121·4	121·8	122·0	121·1	118·5	115·6	114·8	115·1	116.4	117·6
	Oct.	115·4	116·2	116·6	117·2	117·3	116·9	116·0	113·4	111·9	111·5	112·1	112·6
	Nov.	114·2	115·0	116·0	116·6	116·1	117·4	117·1	116·3	114·2	111·8	109·1	108·5
	Dec.	112·3	112·9	113·8	114·7	115·4	115·7	116·5	116·4	115·1	112·2	108·5	108·7
1885.	Jan.	112·0	112·8	113·8	114·1	115·1	115·4	115·8	116·2	114·5	111·0	107·9	107·2
	Feb.	111·0	111·4	112·3	112·8	113·0	113·2	112·3	112·1	110·1	110·2	109·1	107·8
	Mar.	111·0	110·9	111·5	112·6	112·5	112·3	112·5	110·5	109·3	108·9	106·9	105·1
	Apr.	110·9	111·5	112·6	112·4	113·6	113·3	112·0	110·0	108·3	108·1	109·0	109·7
	May	110·1	111·6	111·7	111·4	111·9	111·5	110·5	110·1	110·1	110·3	110·1	110·1
	June	108·4	109·1	109·1	109·2	109·5	110·6	109·0	107·4	107·4	108·2	109·6	110·6
	July	110·4	110·0	110·2	110·5	110·7	111·3	109·3	105·8	105·3	106·8	108·7	110·1
	Aug.	103·7	104·2	103·3	104·1	104·5	104·4	102·2	99·0	98·9	100.3	101·2	102·6
	Sept.	98·6	99·2	99·0	99·6	99·9	100·5	98·2	95·5	93·6	93·3	93·5	92.9
	Oct.	95·5	96·5	97·0	97·5	97·8	97·9	97·1	94·0	91·8	91·8	92·7	93·7
	Nov.	94·8	95·8	96·1	96·9	97·2	97·2	97·3	96·3	94·4	92·1	91·1	90·9
	Dec.	93·0	93·5	94·5	94·9	95·3	95·7	96·3	96·8	95·0	93·2	90·4	89·4
1886.	Jan.	88·9	89·4	88·7	90·5	91·2	92·5	92·6	93·4	93·7	90·9	86·2	84·3
	Feb.	91·5	92·5	93·4	93·7	94·1	94·8	95·5	96·5	96·4	95·2	93·6	90·3
	Mar.	92·9	94·0	92·9	94·6	94·0	92·9	92·7	91·0	89·2	88·1	86·7	86·3
	Apr.	90·0	91·7	91·6	91·8	92·3	93·0	91·1	89·2	88·5	88·1	88·3	88·4
	May	93·4	94·4	94·2	94·1	94·7	94·4	92·9	90·0	89·2	90·3	90·9	92·0
	June	93·0	93·8	93·9	93·6	94·5	94·4	93·7	92·4	93·4	94·4	95·6	95·7

* Corrected for 3 breaks in scale.

AND GEODETIC SURVEY, LOS ANGELES, CAL.

component of the magnetic force.

for each month, 1882 to 1889, 200 divisions + tabular quantity; one division of scale equals 0·000109 of
divisions indicate increasing force.]

13^h	14^h	15^h	16^h	17^h	18^h	19^h	20^h	21^h	22^h	23^h	Midn't	Mean.
124·9	124·9	126·8	126·0	126·1	127·4	128·0	126·9	127·2	129·5	128·1	129·9	127·9
116·4	116·8	117·3	118·6	119·3	117·2	120·2	118·4	119·2	118·5	119·5	121·9	119·2
125·5	127·8	129·3	129·9	130·8	130·2	129·8	128·3	128·9	129·7	129·5	130·4	130·0
130·0	133·3	134·6	135·0	134·6	135·0	135·1	134·4	133·8	133·8	134·7	134·4	134·2
129·4	130·2	131·2	130·2	130·3	130·9	130·5	130·8	131·2	131·4	133·2	132·9	132·8
133·0	134·5	135·4	136·4	135·8	134·2	134·5	133·7	134·6	135·3	135·5	136·9	135·7
136·2	135·7	137·4	138·2	137·4	137·2	137·6	139·0	139·8	139·8	140·4	140·5	138·8
143·2	143·3	142·5	141·4	140·3	139·6	140·3	140·7	140·9	142·0	142·1	143·9	142·2
142·6	142·5	141·5	138·2	137·2	138·3	138·1	140·2	140·5	142·2	142·4	142·4	141·4
136·9	136·6	134·2	134·2	133·0	133·5	133·8	133·9	134·6	135·5	136·3	136·3	136·1
137·1	137·8	138·0	138·2	136·9	137·6	137·7	138·7	139·2	139·0	139·8	140·1	138·3
128·9	130·2	131·4	131·1	129·8	129·2	130·1	130·1	129·0	128·2	129·7	129·9	129·7
123·3	124·5	124·3	124·9	124·5	125·3	125·9	125·8	126·3	126·0	125·7	126·8	124·9
119·3	120·1	120·4	119·7	120·2	120·8	119·8	119·7	119·7	120·2	120·8	120·1	120·5
115·6	117·6	119·3	120·0	120·4	120·2	120·0	119·7	119·5	119·5	119·0	119·8	119·5
114·4	117·7	120·8	122·1	121·7	121·8	121·9	121·7	121·0	120·9	121·0	121·6	120·3
116·8	117·1	118·4	120·0	120·5	121·7	121·8	121·3	120·3	120·6	121·1	122·0	122·2
119·4	121·5	122·6	122·4	121·9	120·8	121·2	122·0	121·9	123·2	122·9	123·7	122·5
124·3	125·4	126·3	125·9	124·5	124·4	125·0	125·4	126·9	127·1	126·7	127·6	126·4
133·0	133·3	131·5	130·5	129·3	129·5	130·1	130·8	131·7	131·8	132·7	133·2	132·0
132·8	132·3	130·8	129·1	127·9	127·9	129·0	129·2	129·8	130·3	130·6	131·0	130·9
127·5	126·5	125·5	123·6	122·2	122·9	124·1	124·7	125·0	125·1	126·8	127·0	126·0
123·3	122·9	122·9	122·5	122·6	124·5	124·7	124·9	125·2	125·4	125·4	125·5	124·3
118·5	119·1	118·3	118·2	118·1	118·4	117·9	118·7	119·5	118·7	119·7	119·6	118·8
113·3	114·0	114·5	114·4	113·8	113·8	112·8	112·3	112·6	113·3	113·5	114·4	114·2
109·3	110·6	111·7	112·7	112·7	113·6	113·0	113·1	112·5	112·2	112·3	112·9	113·3
109·3	111·0	112·5	113·6	113·7	113·5	112·6	111·3	111·3	111·7	111·2	111·9	112·7
108·3	109·8	110·9	111·1	111·0	111·9	111·8	111·7	112·2	112·0	112·2	111·8	112·1
108·2	108·5	109·3	109·2	109·8	109·7	110·5	109·6	110·2	110·0	110·4	110·7	110·5
105·1	106·4	108·7	109·7	109·4	109·5	109·5	109·8	109·5	109·6	109·9	110·6	109·6
111·0	111·0	111·5	111·9	112·1	111·2	110·5	109·6	109·4	109·5	109·8	110·3	110·8
109·5	109·0	108·2	107·0	105·7	106·6	106·9	106·7	107·1	107·6	107·0	109·1	109·2
110·6	109·7	108·9	106·7	104·9	104·5	105·1	106·1	106·3	107·2	108·3	108·3	108·1
110·8	110·6	107·9	105·9	105·1	104·8	106·1	106·2	106·0	107·4	108·2	109·5	108·2
102·6	102·8	102·0	99·9	98·7	99·0	99·4	100·6	100·8	100·5	102·5	103·3	101·7
94·3	96·1	96·3	95·4	95·5	95·7	95·8	96·0	95·4	96·0	96·2	97·6	96·4
94·5	95·3	95·5	95·3	95·6	95·6	94·4	94·9	94·7	94·2	95·1	95·6	95·2
90·6	91·7	93·2	94·0	94·5	94·2	94·2	93·6	93·2	92·8	93·4	93·6	94·1
90·5	90·8	92·4	92·8	93·2	92·8	92·6	92·3	92·5	92·6	91·8	92·2	93·1
84·0	85·3	87·1	88·4	88·6	88·4	88·2	87·6	87·7	88·0	88·1	89·1	88·9
89·9	89·5	89·7	90·5	91·3	91·9	90·8	90·6	91·2	90·9	90·9	91·0	92·3
86·4	88·1	89·7	88·0	89·0	88·1	89·4	89·6	89·0	89·6	89·7	90·3	90·1
88·5	89·1	89·7	88·8	88·8	87·2	88·3	89·7	87·5	89·2	89·5	89·5	89·6
92·1	92·0	91·7	89·6	88·4	88·0	88·3	89·0	90·4	90·3	92·3	93·1	91·5
95·5	93·7	90·3	87·9	88·0	87·6	89·2	90·0	90·4	90·8	91·9	93·5	92·4

MAGNETIC OBSERVATORY OF THE COAST

Differential observations of the horizontal

[Recapitulation of mean hourly values of reduced scale-readings for magnet at normal temperature
horizontal force. Increasing scale

Year.	Month.	1^h	2^h	3^h	4^h	5^h	6^h	7^h	8^h	9^h	10^h	11^h	Noon
1886.	July	90·7	90·9	90·4	90·4	90·5	91·3	89·6	87·4	87·5	87·7	88·7	89·6
	Aug.	90·0	90·2	89·9	89·6	90·3	89·7	87 5	84·1	83·6	84·8	86·2	87·5
	Sept.	87·8	88·6	89·3	89·6	90·0	89·4	86·5	84·0	82·3	83·1	84·7	86·4
	Oct.	83·7	84·4	84·0	85·1	85·1	85·1	83·9	79·7	78·1	79·5	80·9	80·8
	Nov.	78·2	78·1	78·9	79·2	79·7	80·0	79·8	79·1	77·1	75·5	75·0	73·7
	Dec.	75·7	75·8	76·1	76·5	77·6	77·6	78·5	79·2	79·5	77·3	73·4	72·3
1887.	Jan.	74·9	74·5	74·6	75·3	76·3	76·4	77·0	76·9	76·6	72·9	67·2	66·2
	Feb.	73·6	74·0	75·0	75·7	76·2	76·4	77·4	78.6	78·0	76·0	72·5	71·4
	Mar.	76·1	77·2	78·3	77·4	77·5	77·1	77·5	76·6	77·2	77·0	75·9	75·6
	Apr.	77·2	77·1	78·2	78·1	78·7	78·6	77·0	75·1	74·7	74·1	73·6	72·9
	May	76·8	77·2	76·8	77·3	77·6	77·1	76·1	74·9	75·1	74·9	74·8	74·6
	June	79·2	79·0	79·6	79·1	79·1	79·8	78·7	76·8	76·3	76·5	76·5	77·3
	July	78·0	78·5	79·1	78·8	79·1	79·1	77·5	74·6	74·4	75·9	77·0	78·0
	Aug.	74·7	75·4	75·7	75·7	75·7	75·4	73·5	71·9	72·1	73·3	73·3	73·9
	Sept.	71·8	71·4	72·3	72·9	72·5	72·1	70·3	68·6	68·0	68·8	68·6	68·7
	Oct.	68·8	69·6	70·1	70·4	70·6	70·5	69·9	68·5	66·1	64·9	66·4	66·9
	Nov.	65·8	67·1	66·4	66·8	67·3	67·5	68·1	67·2	66·1	64·8	63·3	63·7
	Dec.	62·9	63·4	63·8	64·4	65·0	65·5	65·9	66·0	65·3	63·5	61·5	59·4
1888.	Jan.	59·3	59·1	60·6	61·9	62·2	63·1	63·6	63·7	62·7	60·0	55·7	56·0
	Feb.	63·8	64·4	65·5	65·9	66·4	66·4	65·8	65·6	65·3	64·6	64·0	63·8
	Mar.	66·6	66·9	67·5	68·3	67·9	67·5	67·2	64·9	64·0	63·2	62·3	61·8
	Apr.	67·6	68·5	68·8	68·6	69·0	69·3	68·3	66·5	65·5	63·9	63·6	63·4
	May	68·1	68·7	68·7	68·4	68·7	68·5	67·4	66·2	66·7	66·9	66·9	66·3
	June	69·1	68·7	69·2	69·2	69·5	69·7	68·2	67·1	66·7	68·0	68·4	69·2
	July	67·6	67·6	68·0	67·4	68·0	68·2	66·9	65·1	64·5	65·1	66·3	67·0
	Aug.	64·9	65·5	65·9	65·9	66·0	65·8	63·8	60·7	60·3	61·2	62·8	64·5
	Sept.	62·3	62·2	63·1	63·4	63·8	63·0	60·4	58·1	57·6	59·3	59·6	60·1
	Oct.	59·7	60·1	61·1	61·2	61·2	60·9	60·4	58·5	56·8	56·5	56·8	57·4
	Nov.	56·1	57·2	58·0	57·7	58·2	58·7	58·7	59·3	59·3	57·3	55·3	54·8
	Dec.	56·3	57·6	58·3	58·7	59·1	59·8	59·9	60·5	59·7	58·2	55·8	54·2
1889.	Jan.	56·0	56·3	56·7	57·0	57·6	58·4	59·0	59·5	58·9	56·5	53·6	53·2
	Feb.	55·5	55·9	56·0	56·6	56·9	57·0	56·8	57·3	57·1	55·6	54·3	53·7
	Mar.	59·8	60·4	60·7	60·9	61·0	60·6	60·5	60·0	59·7	60·4	59·7	59·4
	Apr.	66·4	66·4	66·4	66·4	66·6	66·4	65·5	64·1	63·8	63·5	63·8	64·3
	May	66·9	67·1	67·2	67·3	67·2	67·2	66·1	65·2	65·8	66·5	66·9	67·4
	June	71·5	71·7	71·9	71·8	71·8	71·6	71·2	71·3	71·7	72·1	72·2	72·0
	July	73·1	73·3	73·5	73·4	73·2	73·1	72·3	71·5	71·4	72·0	72·5	72·9
	Aug.	72·8	73·2	73·2	73·2	72·9	73·0	71·8	70·4	70·7	71·1	71·9	72·3
	Sept.	71·6	71·7	72·2	71·7	71·6	71·1	69·7	68·0	67·5	67·7	68·0	69·0

AND GEODETIC SURVEY, LOS ANGELES, CAL.

component of the magnetic force.

for each month, 1882 to 1889, 200 divisions + tabular quantity; one division of scale equals 0·000109 of divisions indicate increasing force.]

13^h	14^h	15^h	16^h	17^h	18^h	19^h	20^h	21^h	22^h	23^h	Midn't	Mean.
88·8	88·2	87·8	86·2	84·6	84·8	86·5	87·3	88.7	88·7	89·4	89·6	88·6
88·0	87·5	86·5	85·6	84·9	84·5	84·5	85·9	86·2	86·7	87·8	88·9	87·1
86·3	86·4	85·3	84·8	84·9	86·1	87·3	86·8	87·2	86·1	86·1	87·9	86·5
81·3	79·7	80·7	80·9	81·2	81·5	80·9	81·7	80·8	81·8	82·2	83·3	81·9
73·2	73·3	73·5	75·1	76·7	77·6	77·2	76·2	76·9	77·0	76·5	78·2	76·9
70·6	71·7	72·7	74·2	75·0	74·4	74·5	73·5	74·0	73·9	74·5	74·2	75·1
68·1	70·1	72·7	74·3	74·2	74·1	73·9	74·1	72·9	73·5	73·3	73·8	73·5
71·6	71·5	70·9	71·0	71·7	72·3	71·8	72·0	71·8	71·9	72·1	72·6	73·6
75·5	76·0	75·8	74·7	75·4	75·1	75·1	74·8	75·5	75·3	75·2	75·7	76·2
74·2	75·4	75·2	75·2	74·1	73·3	73·5	73·0	73·4	74·8	75·1	75·2	75·3
75·2	75·4	75·3	74·0	72·7	72·0	71·8	73·0	74·2	73·8	75·8	76·3	75·1
77·5	77·7	76·9	75·9	74·4	74·4	75·3	75·7	76·4	77·4	76·9	78·6	77·3
78·6	78·1	76·3	74·3	73·8	74·3	74·9	75·5	75·8	76·4	76·5	77·4	76·7
73·1	71·3	70·5	69·5	69·3	70·8	71·6	70·7	71·4	72·0	72·8	74·9	72·9
68·4	67·7	67·4	67·4	67·5	67·9	69·4	68·3	70·3	69·0	69·4	70·3	69·5
67·3	67·5	67·2	68·4	68·4	68·6	68·2	68·2	68·4	68·3	68·1	68·7	68·3
64·0	64·2	65·1	65·1	65·5	65·4	65·5	65·0	64·4	64·6	64·6	64·7	65·5
58·9	59·4	61·1	62·3	62·3	62·8	61·8	61·2	61·4	61·9	61·9	62·9	62·7
57·2	58·4	59·9	60·5	59·9	60·3	60·5	60·2	59·1	59·4	59·6	59·2	60·1
64·8	64·7	64·0	63·9	64·2	63·8	63·2	63·7	64·3	63·9	63·8	63·7	64·6
62·5	64·0	64·7	65·2	65·1	65·3	65·1	64·7	64·7	64·9	65·4	66·9	65·3
65·7	66·2	66·5	67·3	66·6	66·6	65·3	65·6	65·6	67·2	66·8	67·2	66·6
67·5	67·0	65·6	64·2	63·6	64·3	63·7	64·5	64·1	64·9	66·5	67·0	66·4
68·2	67·0	66·3	65·0	64·4	64·2	65·4	65·9	66·7	66·8	67·5	68·3	67·4
67·0	66·7	65·2	63·5	61·9	63·2	63·8	65·1	65·4	66·0	66·1	67·1	66·0
65·5	65·2	64·0	62·0	61·9	62·5	62·6	62·8	63·0	63·5	64·1	64·5	63·7
60·7	61·0	60·3	59·8	59·0	59·6	60·4	60·7	60·9	61·1	60·8	62·5	60·8
57·1	57·4	57·4	57·9	58·5	57·8	58·3	57·0	56·7	57·4	58·0	59·0	58·5
53·8	54·4	56·6	57·1	56·9	56·5	56·4	56·0	55·8	56·1	55·6	55·5	56·7
54·4	56·0	57·5	58·4	58·2	58·2	57·4	56·0	55·1	54·8	55·6	56·2	57·3
55·3	57·1	57·6	58·1	57·3	56·4	56·2	55·8	55·9	55·6	55·4	55·5	56·6
53·9	55·0	55·7	56·6	56·6	56·2	56·0	55·3	55·0	55·0	55·1	55·2	55·8
59·6	60·0	60·1	60·4	60·5	60·4	59·7	59·5	59·7	59·5	59·9	59·6	60·1
65·0	65·8	66·2	65·8	65·7	65·3	64·5	64·5	65·0	65·6	65·8	65·7	65·4
67·4	67·4	67·0	66·6	66·3	66·6	66·2	66·3	66·6	66·6	66·6	67·1	66·7
71·8	71·1	70·7	70·7	70·6	71·0	71·3	71·5	71·6	71·7	71·9	71·8	71·5
73·1	72·3	71·6	71·5	71·4	72·3	72·1	72·4	72·4	72·8	72·7	72·9	72·5
72·4	72·4	72·1	72·2	72·2	72·5	72·4	72·5	72·2	72·4	72·5	72·6	72·3
69·7	70·2	70·4	70·3	70·6	70·9	70·9	71·0	71·5	71·7	71·2	71·6	70·4

General examination of the differential series for changes in the horizontal force.—Looking over the values of monthly means, they are seen upon the whole to diminish, as might be expected from our knowledge of the secular diminution of the horizontal component. Closer inspection, however, reveals the fact of several anomalous values at the beginning and at the end of the series, while between these limits the descent is gradual, with an exhibition of six minor undulations corresponding to the annual variation.

The daily means for October and November, 1882, are broken and very irregular. The extremes for October originate in three breaks of the zero of the scale, for which corrections have been applied. These irregularities I attribute to twist in the suspension fibers under the influence of variations of heat and moisture, to which they had not been subjected before. The apparent irregularities in November are due to the great magnetic storm, already referred to in Part II.

Between the middle of February, 1889, and the close of the series in September following there is an anomalous rise, but coupled with the fact of a very feeble and almost obliterated diurnal variation, plainly showing that the motion of the magnet was resisted, probably by spider threads. On February 13, 1889, the observer noticed that something was wrong and turned the mirror, which demanded a correction of −16 divisions to all subsequent readings. Omitting these defective months, also October and November, 1882, our series extends from December, 1882, to February, 1889, inclusive, or covers six years and three months. During this period there is but one day (July 3, 1884) without observation, and altogether there are but a few hourly gaps in the hourly tabulation. These gaps were filled up by interpolation with due regard to the diurnal variation (during the month) and with regard to any progressive change at the time, as explained in Part II.

Such interpolated hourly coördinates are distinguished by brackets in the tabulation.

Connection of the differential series with the absolute measures.—For this connection there are available 225 determinations of H, with corresponding scale readings (s) during the period December, 1882, and February, 1889. The time of reference (t_0) will be the middle of the series, or January 15, 1886, for which epoch we have the mean monthly scale reading less 200, or $s_0 = 96{\cdot}1$ divisions. Dividing the seventy-five months into six groups and taking for each the corresponding values of H from Part I and s from Part III, the absolute measures when referred to t_0 become as follows:

Results of the differential measures of the horizontal intensity from observations recorded at Los Angeles, Cal.—Continued.

Group.	I.	II.	III.	IV.	V.	VI.
Period.	Dec., 1882, to Dec., '83.	Year 1884.	Year 1885.	Year 1886.	Year 1887.	Jan., 1888, to Feb., 1889.
Mean of H (dyne).	0·27308	0·27296	0·27272	0·27262	0·27265	0·27255
Mean of s (divisions)	131	120	100	86	72	61
$s - s_0$.	+ 35	+ 24	+ 4	— 10	— 24	— 35
$-0{\cdot}000109\ (s - s_0)$.	— 0·00382	— 0·00262	— 0·00044	+ 0·00109	+ 0·00262	+ 0·00382
Same in dyne.	— 0·00104	— 0·00071	— 0·00012	+ 0·00030	+ 0·00071	+ 0·00104
H at t_0.	0·27204	0·27225	0·27260	0·27292	0·27336	0·27359
Difference from mean	+ 0·00076	+ 0·00055	+ 0·00020	— 0·00012	— 0·00056	— 0·00079

Hence the relation: $H_s = 0{\cdot}27280 + 0{\cdot}0000297\ (s - 296{\cdot}1)$, expressed in dynes.

The small differences between the referred values, though systematic, must be attributed to the absolute measures and perhaps some small part may be due to other causes.

By means of the above formula we obtain the resulting annual values of H as depending on the monthly mean scale readings, viz:

Year.	s_y	H_y
1883·5	332·8	0·27389
1884·5	322·0	357
1885·5	304·1	304
1886·5	286·7	252
1887·5	272·2	209
1888·5	262·8	181

Annual change of the horizontal component of the force.—The annual change of H, which is the effect of the secular variation during one year, may be exhibited in two ways; first by means of monthly differences, showing the greater or less uniformity in the annual change (a) when brought out for each month, and secondly by deducing a from the annual means.

The following table contains for each month the differences of scale readings for the years 1883 and 1888, for the years 1884 and 1887, and for the years 1885 and 1886; hence in the aggregate nine times the annual change.

Month.	Δs 1883 –'88	Δs 1884 –'87	Δs 1885 –'86	$9a$	a	Month.	Δs 1883 –'88	Δs 1884 –'87	Δs 1885 –'86	$9a$	a
Jan.	74·1	46·8	23·2	144·1	16·0	July.	70·1	49·3	19·6	139·0	15·4
Feb.	68·2	48·6	18·2	135·0	15·0	Aug.	74·6	51·4	14·6	140·6	15·6
Mar.	70·4	46·3	19·5	136·2	15·1	Sept.	68·9	49·3	9·9	128·1	14·2
Apr.	72·2	51·1	21·2	144·5	16·0	Oct.	66·4	45·9	13·3	125·6	14·0
May.	75·8	56·9	17·7	150·4	16·7	Nov.	63·8	47·8	17·2	128·8	14·3
June.	74·0	53·6	15·7	143·3	15·9	Dec.	62·2	50·0	18·0	130·2	14·5
											15·2

Annual decrease a = 15·2 scale divisions, = 0·00166 in parts of H, = 0·000452 of a dyne.

Operating with the annual means we have:

Year.	s_y—200.
1883·5	132·8
1884·5	122·0
1885·5	104·1
1886·5	86·7
1887·5	72·2
1888·5	62·8
Mean 1886·0	96·8

Scale division for any year, $s_y = 96·8 + a\,(t - 1886·0)$; hence the normal equation, $0 = +\,258·4 + 17·50a$, and $a = -\,14·8$ scale divisions, which value is adopted.

Expressed in parts of the force we have $a_1 = -\,0·00161$, a value in very good accord with the deduction made by me in 1885 for stations San Diego and Santa Barbara, Cal., for which $-\,0·0017$ and $-\,0·0014$ were found (see Appendix No. 6, Report for 1885, p. 271). According to the same paper the horizontal intensity was a maximum about 1860, since which time H has been declining. The value of a in dynes is 0·000440.

The absolute measures give a smaller value, but they are considered too rough in comparison with the differential measures.

Annual variation of the horizontal force.—This is readily made out by tabulating for each year the monthly means of the scale readings

Results of the differential measures of the horizontal intensity from observations recorded at Los Angeles, Cal.—Continued.

and correcting the same for annual decrease of force. This correction in scale divisions is as follows:

January,	—6.8	July,	+0·6
February,	—5·5	August,	+1·8
March,	—4·3	September,	+3·1
April,	—3·1	October,	+4·3
May,	—1·8	November,	+5·5
June,	—0·6	December,	+6·8

Applying these corrections we get the corrected means of scale readings:

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Mean
1883	127·4	127·3	131·4	135·7	140·4	140·8	136·7	140·1	132·8	129·2	126·0	126·3	
1884	113·5	116·7	118·2	123·3	130·2	130·3	126·6	126·1	121·9	118·5	118·8	119·5	
1885	105·3	105·0	105·3	107·7	107·4	107·5	108·8	103·5	99·5	99·5	99·6	99·9	
1886	82·1	86·8	85·8	86·5	89·7	91·8	89·2	88·9	89·6	86·2	82·4	81·9	
1887	66·7	68·1	71·9	72·2	73·3	76·7	77·3	74·7	72·6	72·6	71·0	69·5	
1888	53·3	59·1	61·0	63·5	64·6	66·8	66·6	65·5	63·9	62·8	62·2	64·1	
Mean	91·4	93·8	95·6	98·2	100·9	102·3	100·9	99·8	96·7	94·8	93·3	93·5	96·8
Mean—96·8	—5·4	—3·0	—1·2	+1·4	+4·1	+5·5	+4·1	+3·0	—0·1	—2·0	—3·5	—3·3	

The last line constitutes the annual variation, showing a regular annual periodic change with a maximum horizontal force in June and a minimum in January, range 10·9 divisions, or 0·00119 parts of the force, or 0·000324 dyne. This variation depends on the sun's declination.

Inequality of range in annual variation.—It was thought desirable to investigate whether our series indicates an inequality in the range of the annual variation, which may be connected with the sun-spot period. An exact evaluation of the annual variation, however, is a matter of some difficulty, since we must be certain that the instrument has not undergone any sensible change in its adjustment during the year, and secondly, that the correction for change of temperature was satisfactorily applied. Even for self-recording instruments, such as the Adie magnetograph, it requires a combination of two or three years to bring out consistent results. Taking the first three years and the last three years we get the annual variation (A) in scale divisions, as follows:

Periods.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Range.
1883–'5	—4·2	—3·3	—1·3	+2·6	+6·4	+6·6	+4·4	+3·6	—1·5	—3·9	—4·8	—4.4	11·4
1886–'8	—6·5	—2·6	—1·0	+0·2	+2·0	+4·5	+3·8	+2·5	+1·5	0·0	—2·0	—2·1	11·0

Comparison of results for annual variation in H at several stations.

At Dublin, Ireland.*	Max. in June.	Min. in Feb.	Range in parts of H.	·0015
Toronto, Canada.†	July.	Dec.		·0016
Philadelphia, Pa.‡	July.	Jan.		·00088
Los Angeles, Cal.	June.	Jan.		·00119

The annual variation A can be expressed by:

$$A = \overset{sd}{4{\cdot}77} \sin (\theta + 276^\circ{\cdot}4)$$

or

$$0{\cdot}000520 \sin (\theta + 276^\circ{\cdot}4), \text{ expressed in parts of H}$$

where the angle θ counts from January 1 at the rate of 30° a month; the range is accordingly 0·00104 H. The annual variation becomes zero a few days *after* the equinoxes, and reaches its extreme values a few days after the solstices.

Total diurnal variation of the horizontal force.—This variation has been called total, in order to distinguish it from the solar-diurnal variation, in which latter all (large) disturbances are excluded; in the present case no scale readings whatever were omitted from the tabulation. The following table contains for any one month the differences of the monthly mean of 24 hours from the monthly mean for every single hour, *i. e.*, the diurnal variation for every month expressed in scale divisions.

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*Lloyd's Treatise on Magnetism, p. 166. † Walker's Prize Essay for 1865, p. 266.
‡ Coast Survey Report for 1862, p. 201.

DIFFERENTIAL OBSERVATIONS OF THE HORIZONTAL

Differences of monthly means (in scale divisions)

[1 scale division = 0.000109 H. A + sign indicates greater,

Month.	Year.	1^h	2^h	3^h	4^h	5^h	6^h	7^h	8^h	9^h	10^h	11^h	Noon
Jan.	1883	+0·9	+0·8	+1·6	+2·2	+2·4	+3·1	+3·4	+2·4	+1·2	−2·7	−6·6	−5·8
	1884	+0·7	+2·1	+2·5	+2·2	+3·2	+3·5	+3·7	+2·8	−0·2	−5·2	−9·5	−8·7
	1885	−0·1	+0·7	+1·7	+2·0	+3·0	+3·3	+3·7	+4·1	+2·4	−1·1	−4·2	−4·9
	1886	0·0	+0·5	−0·2	+1·6	+2·3	+3·6	+3·7	+4·5	+4·8	+1·0	−2·7	−4·6
	1887	+1·4	+1·0	+1·1	+2·0	+2·8	+2·9	+3·5	+3·4	+3·1	−0·6	−6·3	−7·3
	1888	−0·8	−1·0	+0·5	+1·8	+2·1	+3·0	+3·5	+3·6	+2·6	−0·1	−4·4	−4·1
	1889	−0·6	−0·3	+0·1	+0·4	+1·0	+1·8	+2·4	+2·9	+2·3	−0·1	−3·0	−3·4
	Mean.	+0·2	+0·5	+1·0	+1·7	+2·4	+3·0	+3·4	+3·4	+2·3	−1·3	−5·2	−5·5
Feb.	1883	+1·6	+1·4	+2·2	+2·8	+3·4	+4·1	+4·6	+3·5	+2·5	−0·9	−1·8	−2·1
	1884	+0·7	+1·1	+2·0	+2·6	+2·9	+3·4	+4·5	+5·5	+5·0	+2·6	−1·5	−5·0
	1885	+0·5	+0·9	+1·8	+2·3	+2·5	+2·7	+1·8	+1·6	−0·4	−0·3	−1·4	−2·7
	1886	−0·8	+0·2	+1·1	+1·4	+1·8	+2·5	+3·2	+4·2	+4·1	+2·9	+1·3	−2·0
	1887	0·0	+0·4	+1·4	+2·1	+2·6	+2·8	+3·8	+5·0	+4·4	+2·4	−1·1	−2·2
	1888	−0·8	−0·2	+0·9	+1·3	+1·8	+1·8	+1·2	+1·0	+0·7	0·0	−0·6	−0·8
	1889	−0·3	+0·1	+0·2	+0·8	+1·1	+1·2	+1·0	+1·5	+1·3	−0·2	−1·5	−2·1
	Mean.	+0·1	+0·6	+1·4	+1·9	+2·3	+2·6	+2·9	+3·2	+2·5	+0·9	−0·9	−2·4
Mar.	1883	+0·6	+1·3	+1·9	+2·5	+2·7	+2·7	+1·5	+0·6	−0·4	−0·7	−1·7	−2·5
	1884	+1·6	+3·1	+3·1	+3·6	+3·1	+3·4	+2·5	−0·2	−3·2	−3·6	−3·8	−3·9
	1885	+1·4	+1·3	+1·9	+3·0	+2·9	+2·7	+2·9	+0·9	−0·3	−0·7	−2·7	−4·5
	1886	+2·8	+3·9	+2·8	+4·5	+3·9	+2·8	+2·6	+0·9	−0·9	−2·0	−3·4	−3·8
	1887	−0·1	+1·0	+2·1	+1·2	+1·3	+0·9	+1·3	+0·4	+1·0	+0·8	−0·3	−0·6
	1888	+1·3	+1·6	+2·2	+3·0	+2·6	+2·2	+1·9	+0·4	−1·3	−2·1	−3·0	−3·5
	Mean.	+1·3	+2·0	+2·3	+3·0	+2·8	+2·4	+2·1	+0·4	−0·8	−1·4	−2·5	−3·1
Apr.	1883	+3·4	+2·8	+2·3	+2·8	+2·5	+2·4	+2·0	−0·2	−2·4	−3·6	−3·6	−3·0
	1884	+1·7	+1·8	+2·9	+3·1	+2·8	+3·4	+0·7	−0·7	−1·5	−1·4	−3·2	−3·3
	1885	+0·1	+0·7	+1·8	+1·6	+2·8	+2·5	+1·2	−0·8	−2·5	−2·7	−1·8	−1·1
	1886	+0·4	+2·1	+2·0	+2·2	+2·7	+3·4	+1·5	−0·4	−1·1	−1·5	−1·3	−1·2
	1887	+1·9	+1·8	+2·9	+2·8	+3·4	+3·3	+1·7	−0·2	−0·6	−1·2	−1·7	−2·4
	1888	+1·0	+1·9	+2·2	+2·0	+2·4	+2·7	+1·7	−0·1	−1·1	−2·7	−3·0	−3·2
	Mean.	+1·4	+1·8	+2·4	+2·4	+2·8	+3·0	+1·5	−0·4	−1·5	−2·2	−2·4	−2·4

FORCE, DECEMBER, 1882, TO FEBRUARY, 1889, INCLUSIVE.

of each hour from mean of month.

a — sign less force than the mean for the month.]

13^h	14^h	15^h	16^h	17^h	18^h	19^h	20^h	21^h	22^h	23^h	Mdn't.
—4·2	—0·9	+0·4	+0·8	+0·4	+0·8	+0·9	+0·2	—0·4	—0·4	+0·5	+0·2
—5·9	—2·6	+0·5	+1·8	+1·4	+1·5	+1·6	+1·4	+0·7	+0·6	+0·7	+1·3
—3·8	—2·3	—1·2	—1·0	—1·1	—0·2	—0·3	—0·4	+0·1	—0·1	+0·1	—0·3
—4·9	—3·6	—1·8	—0·5	—0·3	—0·5	—0·7	—1·3	—1·2	—0·9	—0·8	+0·2
—5·4	—3·4	—0·8	+0·8	+0·7	+0·6	+0·4	+0·6	—0·6	0·0	—0·2	+0·3
—2·9	—1·7	—0·2	+0·4	—0·2	+0·2	+0·4	+0·1	—1·0	—0·7	—0·5	—0·9
—1·3	+0·5	+1·0	+1·5	+0·7	—0·2	—0·4	—0·8	—0·7	—1·0	—1·2	—1·1
—4·1	—2·0	—0·3	+0·5	+0·2	+0·3	+0·3	0·0	—0·4	—0·4	—0·2	0·0
—3·4	—2·6	—1·6	—2·6	—2·5	—1·9	—2·3	—2·0	—1·6	—1·4	+0·4	+0·1
—5·4	—5·1	—3·8	—2·2	—1·7	—0·5	—0·4	—0·9	—1·9	—1·6	—1·1	—0·2
—2·3	—2·0	—1·2	—1·3	—0·7	—0·8	0·0	—0·9	—0·3	—0·5	—0·1	+0·2
—2·4	—2·8	—2·6	—1·8	—1·0	—0·4	—1·5	—1·7	—1·1	—1·4	—1·4	—1·3
—2·0	—2·1	—2·7	—2·6	—1·9	—1·3	—1·8	—1·6	—1·8	—1·7	—1·5	—1·0
+0·2	+0·1	—0·6	—0·7	—0·4	—0·8	—1·4	—0·9	—0·3	—0·7	—0·8	—0·9
—1·9	—0·8	—0·1	+0·8	+0·8	+0·4	+0·2	—0·5	—0·8	—0·8	—0·7	—0·6
—2·5	—2·2	—1·8	—1·5	—1·1	—0·8	—1·0	—1·2	—1·1	—1·2	—0·7	—0·5
—2·7	—1·2	—0·3	+0·7	+0·1	—1·5	—1·2	—2·0	—1·1	—0·4	—0·2	+1·2
—3·1	—1·0	+0·1	—0·1	—0·6	—1·7	—1·3	—0·5	—0·6	+0·7	+0·4	+1·2
—4·5	—3·2	—0·9	+0·1	—0·2	—0·1	—0·1	+0·2	—0·1	0·0	—0·1	+1·0
—3·7	—2·0	—0·4	—2·1	—1·1	—2·0	—0·7	—0·5	—1·1	—0·5	—0·4	+0·2
—0·7	—0·2	—0·4	—1·5	—0·8	—1·1	—1·1	—1·4	—0·7	—0·9	—1·0	—0·5
—2·8	—1·3	—0·6	—0·1	—0·2	0·0	—0·2	—0·6	—0·6	—0·4	+0·1	+1·6
—2·9	—1·5	—0·4	—0·5	—0·5	—1·1	—0·8	—0·8	—0·7	—0·2	—0·2	+0·8
—2·6	—3·1	—1·4	—0·6	—1·4	—1·6	—1·2	+0·2	+1·0	+1·0	+1·6	+1·7
—2·1	—1·0	—0·1	—0·5	—1·9	—2·0	—1·4	—1·0	+0·5	+0·7	+0·3	+1·2
+0·2	+0·2	+0·7	+1·1	+1·3	+0·4	—0·3	—1·2	—1·4	—1·3	—1·0	—0·5
—1·1	—0·5	+0·1	—0·8	—0·8	—2·4	—1·3	+0·1	—2·1	—0·4	—0·1	—0·1
—1·1	+0·1	—0·1	—0·1	—1·2	—2·0	—1·8	—2·3	—1·9	—0·5	—0·2	—0·1
—0·9	—0·4	—0·1	+0·7	0·0	0·0	—1·3	—1·0	—1·0	+0·6	+0·2	+0·6
—1·3	—0·8	—0·2	0·0	—0·7	—1·3	—1·2	—0·9	—0·8	0·0	+0·1	+0·5

DIFFERENTIAL OBSERVATIONS OF THE HORIZONTAL

Differences of monthly means (in scale divisions)

[1 scale division = 0·000109 H. A + sign indicates greater

Month.	Year.	1^h	2^h	3^h	4^h	5^h	6^h	7^h	8^h	9^h	10^h	11^h	Noon.
May.	1883	+1·3	+1·1	+1·1	+1·0	+1·7	+2·0	+1·0	−1·7	−1·8	−0·6	−0·3	+0·9
	1884	+1·1	+1·2	+0·6	+0·5	+1·2	+1·2	−0·1	−1·4	−0·4	+1·0	+0·7	+0·5
	1885	+0·9	+2·4	+2·5	+2·2	+2·7	+2·3	+1·3	+0·9	+0.9	+1·1	+0·9	+0·9
	1886	+1·9	+2·9	+2·7	+2·6	+3·2	+2·9	+1·4	−1·5	−2·3	−1·2	−0·6	+0·5
	1887	+1·7	+2·1	+1·7	+2·2	+2·5	+2·0	+1·0	−0·2	0·0	−0·2	−0·3	−0·5
	1888	+1·7	+2·3	+2·3	+2·0	+2·3	+2·1	+1·0	−0·2	+0·3	+0·5	+0·5	−0·1
	Mean.	+1·4	+2·0	+1·8	+1·8	+2·3	+2·1	+0·9	−0·7	−0·6	+0·1	+0·2	+0·4
June.	1883	+1·8	+2·9	+1·4	+1·9	+1·9	+1·7	−0·3	−2·3	−2·4	0·0	+1·8	+2·3
	1884	−0·1	+1·0	+0·6	+1·2	+1·4	+2·0	+0·7	0·0	+0·1	+1·2	+0·9	+1·8
	1885	+0·3	+1·0	+1·0	+1·1	+1·4	+2·5	+0·9	−0·7	−0·7	+0·1	+1·5	+2·5
	1886	+0·6	+1·4	+1·5	+1·2	+2·1	+2·0	+1·3	0·0	+1·0	+2·0	+3·2	+3·3
	1887	+1·9	+1·7	+2·3	+1·8	+1·8	+2·5	+1·4	−0·5	−1·0	−0·8	−0·8	0·0
	1888	+1·7	+1·3	+1·8	+1·8	+2·1	+2·3	+0·8	−0·3	−0·7	+0·6	+1·0	+1·8
	Mean.	+1·0	+1·6	+1·4	+1·5	+1·8	+2·2	+0·8	−0·6	−0·6	+0·5	+1·3	+2·0
July.	1883	+2·4	+2·1	+1.7	+2·1	+2·5	+3·0	+1·6	+0·1	−1·3	−0·5	+0·3	+0·7
	1884	+0·4	+1·3	+1·2	+1·6	+2·2	+2·2	+0·6	−1·9	−1·5	0·0	+1·5	+2·5
	1885	+2·2	+1·8	+2·0	+2·3	+2·5	+3·1	+1·1	−2·4	−2·9	−1·4	+0·5	+1·9
	1886	+2·1	+2·3	+1·8	+1·8	+1·9	+2·7	+1·0	−1·2	−1·1	−0·9	+0·1	+1·0
	1887	+1·3	+1·8	+2·4	+2·1	+2·4	+2·4	+0·8	−2·1	−2·3	−0·8	+0·3	+1·3
	1888	+1·6	+1·6	+2·0	+1·4	+2·0	+2·2	+0·9	−0·9	−1·5	−0·9	+0·3	+1·0
	Mean.	+1·7	+1·8	+1·8	+1·9	+2·2	+2·6	+1·0	−1·4	−1·8	−0·8	+0·5	+1·4
Aug.	1883	+1·5	+2·3	+2·2	+2.2	+2·0	+2·4	−0·1	−3·7	−3·6	−2·3	−1·9	−1·5
	1884	+2·6	+1·9	+2·5	+2·7	+2·5	+2·1	−0·5	−3·1	−2·3	−2·2	−2·2	−1·3
	1885	+2·0	+2·5	+1·6	+2·4	+2·8	+2·7	+0·5	−2·7	−2·8	−1·4	−0·5	+0·9
	1886	+2·9	+3·1	+2·8	+2·5	+3·2	+2·6	+0·4	−3·0	−3·5	−2·3	−0·9	+0·4
	1887	+1·8	+2·5	+2·8	+2·8	+2·8	+2·5	+0·6	−1·0	−0·8	+0·4	+0·4	+1·0
	1888	+1·2	+1·8	+2·2	+2·2	+2·3	+2·1	+0·1	−3·0	−3·4	−2·5	−0·9	+0·8
	Mean.	+2·0	+2·3	+2·4	+2·5	+2·6	+2·4	+0·2	−2·8	−2·7	−1·7	−1·0	0·0

FORCE, DECEMBER, 1882, TO FEBRUARY, 1889, INCLUSIVE.

of each hour from mean of month—Continued.

a — sign less force than the mean for the month.]

13^h	14^h	15^h	16^h	17^h	18^h	19^h	20^h	21^h	22^h	23^h	Midn't.
+1.0	+1.1	+0·3	—0·8	—1·9	—2·6	—1·9	—1·5	—1·3	—0·2	—0·1	+1·7
+1·0	+1·3	—0·5	—1·5	—2·7	—2·5	—1·9	—1·2	—0·3	—0·2	+0·7	+1·2
+0·3	—0·2	—1·0	—2·2	—3·5	—2·6	—2·3	—2·5	—2·1	—1·6	—2·2	—0·1
+0·6	+0·5	+0.2	—1·9	—3·1	—3·5	—3·2	—2·5	—1·1	—1·2	+0·8	+1·6
+0·1	+0·3	+0·2	—1·1	—2·4	—3·1	—3·3	—2·1	—0·9	—1·3	+0·7	+1·2
+1·1	+0·6	—0.8	—2·2	—2·8	—2·1	—2·7	—1·9	—2·3	—1·5	+0·1	+0.6
+0·7	+0·6	—0·3	—1·6	—2·7	—2·7	—2·6	—2·0	—1·3	—1·0	0·0	+1·0
+1·2	+1·1	+0·1	—3·2	—4·2	—3·1	—3·3	—1·2	—0·9	+0·8	+1·0	+1·0
+1·9	+1·4	—0·1	—1·8	—3·0	—3·0	—1·9	—1·7	—1·1	—0·6	—0·3	+0·1
+2·5	+1·6	+0·8	—1·4	—3·2	—3·6	—3·0	—2·0	—1·8	—0·9	+0·2	+0·2
+3·1	+1·3	—2·1	—4·5	—4·4	—4·8	—3·2	—2·4	—2·0	—1·6	—0·5	+1·1
+0·2	+0·4	—0·4	—1·4	—2·9	—2·9	—2·0	—1·6	—0·9	+0·1	—0·4	+1·3
+0·8	—0·4	—1·1	—2·4	—3·0	—3·2	—2·0	—1·5	—0·7	—0·6	+0·1	+0·9
+1·6	+0·9	—0·5	—2·4	—3·4	—3·4	—2·6	—1·7	—1·2	—0·5	0·0	+0·8
+0·8	+0·5	—1·9	—1·9	—3·1	—2·6	—2·3	—2·2	—1·5	—0·6	+0·2	+0·2
+1·5	+0·5	—0·5	—2·4	—3·8	—3·1	—1·9	—1·3	—1·0	—0·9	+0·8	+1·0
+2·6	+2·4	—0·3	—2·3	—3·1	—3·4	—2·1	—2·0	—2·2	—0·8	0·0	+1·3
+0·2	—0·4	—0·8	—2·4	—4·0	—3·8	—2·1	—1·3	+0·1	+0·1	+0·8	+1·0
+1·9	+1·4	—0·4	—2·4	—2·9	—2·4	—1·8	—1·2	—0·9	—0·3	—0·2	+0·7
+1·0	+0·7	—0·8	—2·5	—4·1	—2·8	—2·2	—0·9	—0.6	0·0	+0·1	+1·1
+1·3	+0·8	—0·8	—2·3	—3·5	—3·0	—2·1	—1·5	—1·0	—0·4	+0·3	+0·9
—1·2	—0·5	—0·3	—0·1	—1·4	—0·7	—0·6	+0·4	+0·9	+0·7	+1·5	+1·8
—1·0	—1·4	—1·4	—1·8	—1·7	+0·2	+0·4	+0·6	+0·9	+1·1	+1·1	+1·2
+0·9	+1·1	+0·3	—1·8	—3·0	—2·7	—2·3	—1·1	—0·9	—1·2	+0·8	+1·6
+0·9	+0·4	—0·6	—1·5	—2·2	—2·6	—2·6	—1·2	—0·9	—0·4	+0·7	+1·8
+0·2	—1·6	—2·4	—3·4	—3·6	—2·1	—1·3	—2·2	—1·5	—0·9	—0·1	+2·0
+1·8	+1·5	+0·3	—1·7	—1·8	—1·2	—1·1	—0·9	—0·7	—0·2	+0·4	+0·8
+0·3	—0·1	—0·7	—1·7	—2·3	—1·5	—1·2	—0·7	—0·4	—0·1	+0·7	+1·5

DIFFERENTIAL OBSERVATIONS OF THE HORIZONTAL

Differences of monthly means (in scale divisions)

[1 scale division = 0·000109 H. A + sign indicates greater,

Month.	Year.	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	Noon.
Sept.	1883	+1·8	+2·0	+2·0	+3·1	+2·5	+3·4	+0·4	−2·9	−3·9	−3·6	−3·5	−2·5
	1884	+1·9	+1·6	+2·6	+3·0	+3·2	+2·3	−0·3	−3·2	−4·0	−3·7	−2·4	−1.2
	1885	+2·2	+2·8	+2·6	+3·2	+3·5	+4·1	+1·8	−0·9	−2·8	−3·1	−2·9	−3·5
	1886	+1·3	+2·1	+2·8	+3·1	+3·5	+2·9	0·0	−2·5	−4·2	−3·4	−1·8	−0·1
	1887	+2·3	+1·9	+2·8	+3·4	+3·0	+2·6	+0·8	−0·9	−1·5	−0·7	−0·9	−0·8
	1888	+1·5	+1·4	+2·3	+2·6	+3·0	+2·2	−0·4	−2·7	−3·2	−1·5	−1·2	−0.7
	Mean.	+1·8	+2·0	+2·5	+3·1	+3·1	+2·9	+0·4	−2·2	−3·3	−2·7	−2·1	−1·5
Oct.	1883	+2·0	+2·5	+3·4	+3·6	+3·4	+2·7	+0·5	−3·6	−4·8	−5·0	−4·8	−4·1
	1884	+1·2	+2·0	+2·4	+3·0	+3·1	+2·7	+1·8	−0·8	−2·3	−2·7	−2·1	−1·6
	1885	+0·3	+1·3	+1·8	+2·3	+2·6	+2·7	+1·9	−1·2	−3·4	−3·4	−2·5	−1·5
	1886	+1·8	+2·5	+2·1	+3·2	+3·2	+3·2	+2·0	−2·2	−3·8	−2·4	−1·0	−1·1
	1887	+0·5	+1·3	+1·8	+2·1	+2·3	+2·2	+1·6	+0·2	−2·2	−3·4	−1·9	−1·4
	1888	+1·2	+1·6	+2·6	+2·7	+2·7	+2·4	+1·9	0·0	−1·7	−2·0	−1·7	−1·1
	Mean.	+1·2	+1·9	+2·4	+2·8	+2·9	+2·6	+1·6	−1·3	−3·0	−3·2	−2·3	−1·8
Nov.	1883	+0·5	+1·2	+1·8	+3·5	+3·7	+3·1	+2·8	+0·6	−1·7	−3·8	−4·2	−2·6
	1884	+0·9	+1·7	+2·7	+3·3	+2·8	+4·1	+3·8	+3·0	+0·9	−1·5	−4·2	−4·8
	1885	+0·7	+1·7	+2·0	+2·8	+3·1	+3·1	+3·2	+2·2	+0·3	−2·0	−3·0	−3·2
	1886	+1·3	+1·2	+2·0	+2·3	+2·8	+3·1	+2·9	+2·2	+0·2	−1·4	−1·9	−3·2
	1887	+0·3	+1·6	+0·9	+1·3	+1·8	+2·0	+2·6	+1·7	+0·6	−0·7	−2·2	−1·8
	1888	−0·6	+0·5	+1·3	+1·0	+1·5	+2·0	+2·0	+2·6	+2·6	+0·6	−1·4	−1·9
	Mean.	+0·5	+1·3	+1·8	+2·4	+2·6	+2·9	+2·9	+2·0	+0·5	−1·5	−2·8	−2·9
Dec.	1882	−0·1	+0·2	+1·2	+1·3	+1·9	+2·4	+3·6	+3·9	+3·2	+0·2	−3·6	−4·8
	1883	+0·1	+0·7	+1·8	+2·0	+3·0	+3·8	+4·0	+2·8	+0·8	−3·0	−5·8	−6·1
	1884	−0·4	+0·2	+1·1	+2·0	+2·7	+3·0	+3·8	+3·7	+2·4	−0·5	−4·2	−4·0
	1885	−0·1	+0·4	+1·4	+1·8	+2·2	+2·6	+3·2	+3·7	+1·9	+0·1	−2·7	−3·7
	1886	+0·6	+0·7	+1·0	+1·4	+2·5	+2·5	+3·4	+4·1	+4·4	+2·2	−1·7	−2·8
	1887	+0·2	+0·7	+1·1	+1·7	+2·3	+2·8	+3·2	+3·3	+2·6	+0·8	−1·2	−3·3
	1888	−1·0	+0·3	+1·0	+1·4	+1·8	+2·5	+2·6	+3·2	+2·4	+0·9	−1·5	−3·1
	Mean.	−0·1	+0·5	+1·2	+1·7	+2·3	+2·8	+3·4	+3·5	+2·5	+0·1	−3·0	−4·0

FORCE, DECEMBER, 1882, TO FEBRUARY, 1889, INCLUSIVE.

of each hour from mean of month—Continued.

a — sign less, force than the mean for the month.]

13^h	14^h	15^h	16^h	17^h	18^h	19^h	20^h	21^h	22^h	23^h	Midn't.
—0·8	+0·5	+1·7	+1·4	+0·1	—0.5	+0·4	+0·4	—0·7	—1·5	0·0	+0·2
—0·3	+0·3	—0·5	—0·6	—0·7	—0·4	—0·9	—0·1	+0·7	—0·1	+0·9	+0·8
—2·1	—0·3	—0·1	—1·0	—0·9	—0·7	—0·6	—0·[illegible]	—1·0	—0·4	—0·2	+1·2
—0·2	—0·1	—1·2	—1·7	—1·6	—0·4	+0·8	+0·3	+0·7	—0·4	—0·4	+1·4
—1·1	—1·8	—2·1	—2·1	—2·0	—1·6	—0·1	—1·2	+0·8	—0·5	—0·1	+0·8
—0·1	+0·2	—0·5	—1·0	—1·8	—1·2	—0·4	—0·1	+0·1	+0·3	0·0	+1·7
—0·8	—0·2	—0·4	—0·8	—1·1	—0·8	—0·1	—0·2	+0·1	—0·4	0·0	+1·0
—1·6	—0·4	—0·6	0·0	—0·4	+0·4	+1·0	+0·9	+1·4	+1·1	+0·8	+1·9
—0·9	—0·2	+0·3	+0·2	—0·4	—0·4	—1·4	—1·9	—1·6	—0·9	—0·7	+0·2
—0·7	+0·1	+0·3	+0·1	+0·4	+0·4	—0·8	—0·3	—0·5	—1·0	—0·1	+0·4
—0·6	—2·2	—2·1	—1·0	—0·7	—0·4	—1·0	—0·2	—1·1	—0·1	+0·3	+1·4
—1·0	- 0·8	—1·1	+0·1	+0·1	+0·3	—0·1	—0·1	+0·1	0·0	—0·2	+0·4
—1·4	—1.1	—1·1	—0·6	0·0	—0·7	—0·2	—1·5	—1·8	—1·1	—0·5	+0·5
—1·0	—0·8	—0·7	—0·2	—0·2	—0·1	—0·4	—0·5	—0·6	—0·3	—0·1	+0·8
—1·2	—0·4	—0·1	—0·8	—0·3	+0·3	—0·7	—0·8	—0·8	—0·3	+0·3	—0·4
—4·0	—2·7	—1·6	—0·6	—0·6	+0·3	—0·3	—0·2	—0·8	—1·1	—1·0	—0·4
—3·5	—2·4	—0·9	—0·1	+0·4	+0·1	—0·1	—0·5	—0·9	—1·3	—0·7	—0·5
—3·7	—3·6	—3·4	—1·8	—0·2	+0·7	+0·3	—0·7	0·0	+0·1	—0·4	+1·3
—1·5	—1·3	—0·4	—0·4	0·0	—0·1	0·0	—0·5	—1·1	—0·9	—0·9	—0·8
—2·9	—2·3	—0·1	+0·4	+0·2	—0·2	—0·3	—0·7	—0·9	—0·6	—1·1	—1·2
—2·8	—2·1	—1·1	—0·6	—0·1	+0 2	—0·2	—0·6	—0·8	- 0·7	—0·6	—0·3
—4·5	—2·2	—0·7	—0·1	+0·8	+0·2	—0·2	—1·7	—1·1	—0·3	—0·5	+0·4
—3·9	—1·9	—0·2	+0·5	+0·9	+0·7	+0·5	+0·2	0·0	0·0	—0·5	+0·3
—3·4	—1·7	—0·2	+0·9	+1·0	+0·8	—0·1	—1·4	—1·4	—1·0	—1·5	—0·8
—2·6	—2·3	—0·7	—0·3	+0·1	—0·3	—0·5	—0·8	—0·6	—0·5	—1·3	—0·9
—4·5	—3·4	—2·4	—0·9	—0·1	—0·7	—0·6	—1·6	—1·1	—1·2	—0·6	—0·9
—3·8	—3·3	—1·6	—0·4	—0·4	+0·1	—0·9	—1·5	—1·3	—0·8	—0·8	+0·2
—2·9	—1·3	+0·2	+1·1	+0·9	+0·9	+0·1	—1·3	—2.2	—2·5	—1·7	—1.1
—3·7	—2·3	—0·8	+0·1	+0·4	+0·3	—0·3	—1·2	—1·1	—0·9	—1·0	—0·4

Recapitulation of results for total solar diurnal variation of the horizontal force at Los Angeles, between December, 1882, and February, 1889, inclusive, expressed in scale divisions.

[A + sign indicates greater, a — sign less force than the mean of the day. One division equals 0·000109 H.]

1882–'89.	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	Noon.
Jan.	+0·2	+0·5	+1·0	+1·7	+2·4	+3·0	+3·4	+3·4	+2·3	−1·3	−5·2	−5·5
Feb.	+0·1	+0·6	+1·4	+1·9	+2·3	+2·6	+2·9	+3·2	+2·5	+0·9	−0·7	−2·4
Mar.	+1·3	+2·0	+2·3	+3·0	+2·8	+2·4	+2·1	+0·4	−0·8	−1·4	−2·5	−3·1
April.	+1·4	+1·8	+2·4	+2·4	+2·8	+3·0	+1·5	−0·4	−1·5	−2·2	−2·4	−2·4
May.	+1·4	+2·0	+1·8	+1·8	+2·3	+2·1	+0·9	−0·7	−0·6	+0·1	+0·2	+0·4
June.	+1·0	+1·6	+1·4	+1·5	+1·8	+2·2	+0·8	−0·6	−0·6	+0·5	+1·3	+2·0
July.	+1·7	+1·8	+1·8	+1·9	+2·2	+2·6	+1·0	−1·4	−1·8	−0·8	+0·5	+1·4
Aug.	+2·0	+2·3	+2·4	+2·5	+2·6	+2·4	+0·2	−2·8	−2·7	−1·7	−1·0	0·0
Sept.	+1·8	+2·0	+2·5	+3·1	+3·1	+2·9	+0·4	−2·2	−3·3	−2·7	−2·1	−1·5
Oct.	+1·2	+1·9	+2·4	+2·8	+2·9	+2·6	+1·6	−1·3	−3·0	−3·2	−2·3	−1·8
Nov.	+0·5	+1·3	+1·8	+2·4	+2·6	+2·9	+2·9	+2·0	+0·5	−1·5	−2·8	−2·9
Dec.	−0·1	+0·5	+1·2	+1·7	+2·3	+2·8	+3·4	+3·5	+2·5	+0·1	−3·0	−4·0

1882–'89.	13h	14h	15h	16h	17h	18h	19h	20h	21h	22h	23h	Midn't.
Jan.	−4·1	−2·0	−0·3	+0·5	+0·2	+0·3	+0·3	0·0	−0·4	−0·4	−0·2	0·0
Feb.	−2·5	−2·2	−1·8	−1·5	−1·1	−0·8	−1·0	−1·2	−1·1	−1·2	−0·7	−0·5
Mar.	−2·9	−1·5	−0·4	−0·5	−0·5	−1·1	−0·8	−0·8	−0·7	−0·2	−0·2	+0·8
Apr.	−1·3	−0·8	−0·2	−0·0	−0·7	−1·3	−1·2	−0·9	−0·8	0·0	+0·1	+0·5
May.	+0·7	+0·6	−0·3	−1·6	−2·7	−2·7	−2·6	−2·0	−1·3	−1·0	0·0	+1·0
June.	+1·6	+0·9	−0·5	−2·4	−3·4	−3·4	−2·6	−1·7	−1·2	−0·5	0·0	+0·8
July.	+1·3	+0·8	−0·8	−2·3	−3·5	−3·0	−2·1	−1·5	−1·0	−0·4	+0·3	+0·9
Aug.	+0·3	−0·1	−0·7	−1·7	−2·3	−1·5	−1·2	−0·7	−0·4	−0·1	+0·7	+1·5
Sept.	−0·8	−0·2	−0·4	−0·8	−1·1	−0·8	−0·1	−0·2	+0·1	−0·4	0·0	+1·0
Oct.	−1·0	−0·8	−0·7	−0·2	−0·2	−0·1	−0·4	−0·5	−0·6	−0·3	−0·1	+0·8
Nov.	−2·8	−2·1	−1·1	−0·6	−0·1	+0·2	−0·2	−0·6	−0·8	−0·7	−0·6	−0·3
Dec.	−3·7	−2·3	−0·8	+0·1	+0·4	+0·3	−0·3	−1·2	−1·1	−0·9	−1·0	−0·4

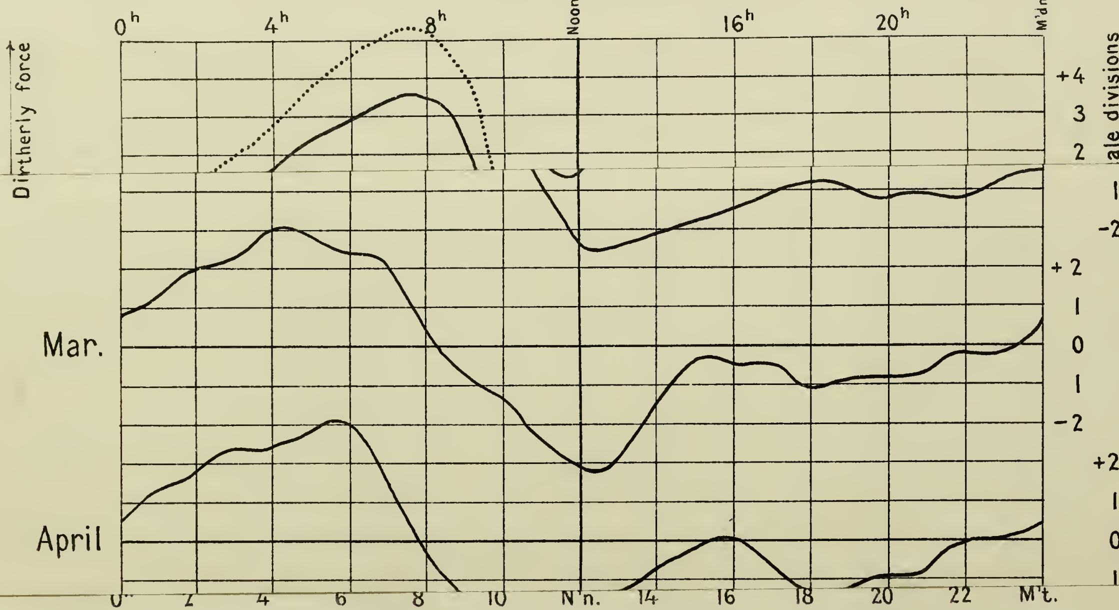
The character of the total diurnal variation for each month of the year is shown on the accompanying diagram (illustration No. 1), which was constructed directly from the preceding tabular numbers.*

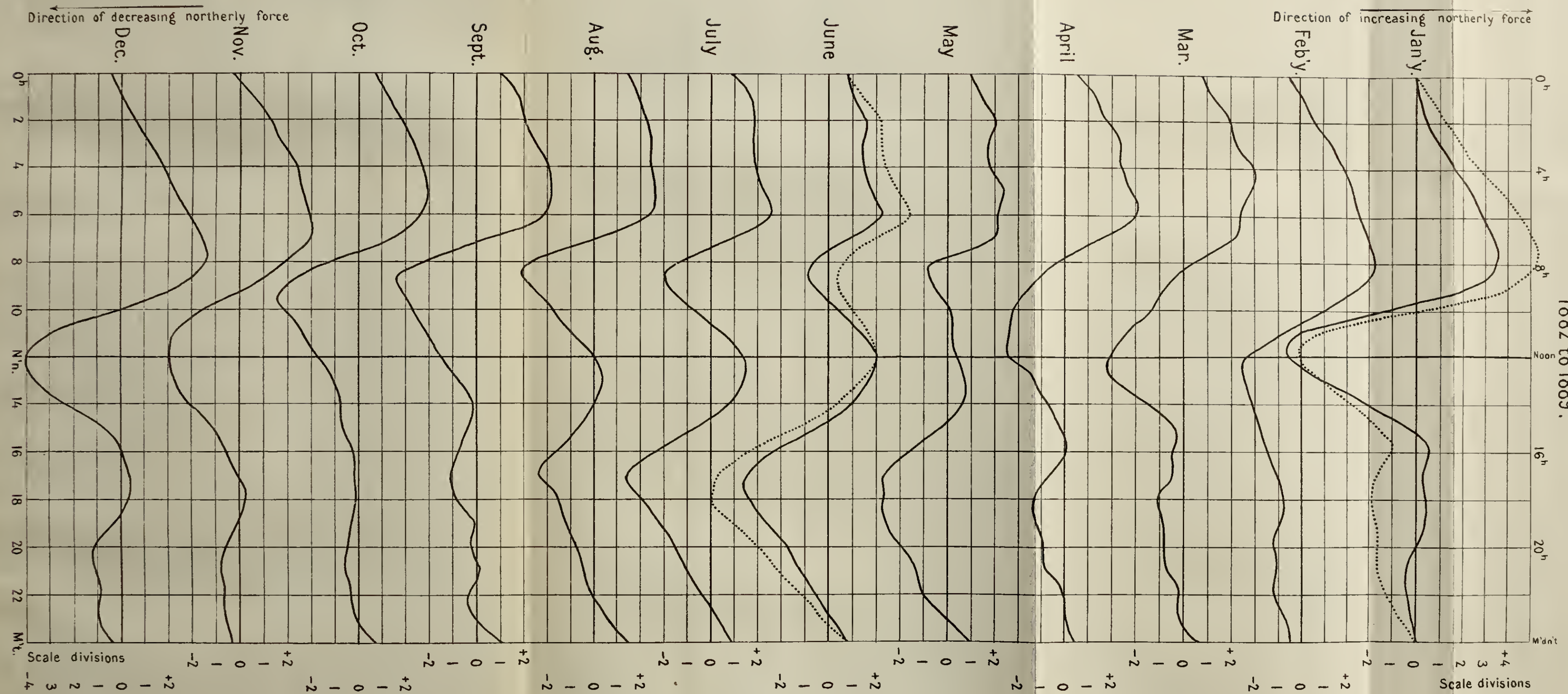
In general, the horizontal force exhibits a maximum value about 6 o'clock a. m., followed a few hours later by a minimum, which, however, during the summer season, becomes a subordinate minimum, the principal one occurring about 5 o'clock p. m. As a peculiarity of the station we may note the *weak* development of the secondary afternoon maximum, and the extraordinary low intensity in the afternoon minimum during the warmer part of the year.

*To bring out prominently the effect of the temperature correction ($q = 2·48$ scale divisions), the dotted curves for January and June were introduced; these are taken directly from the tabulated hourly readings of the photographic traces *without* any reduction for temperature changes of magnet.

No. 1

Monthly values of the
Total Solar-diurnal variation of the horizontal force at
Los Angeles, Cal. from 6¼ years of observation
1882 to 1889.

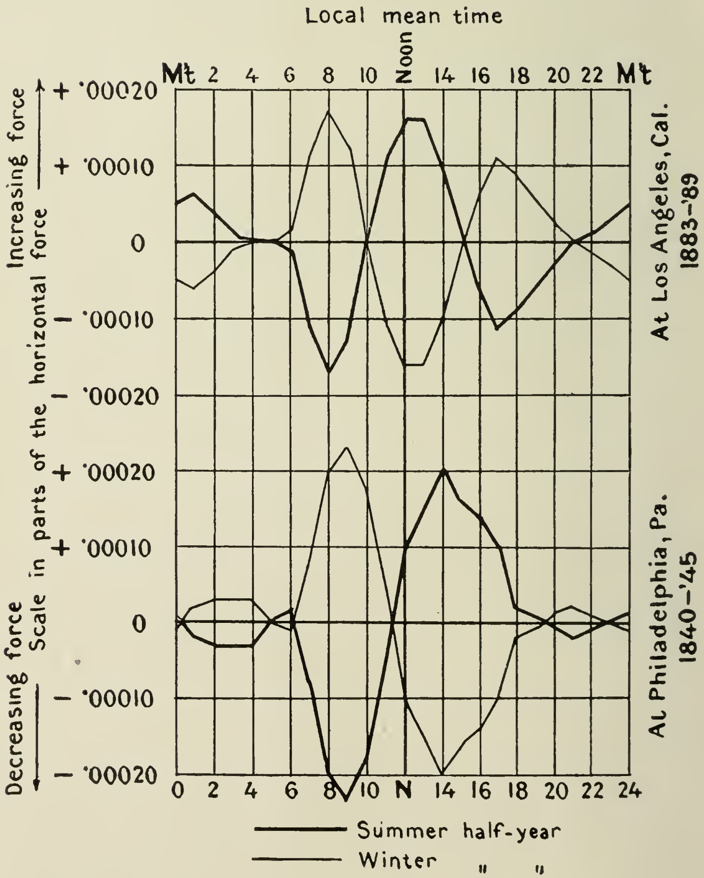




One scale division = 0.000109 parts of the horizontal force.

Monthly values of the Total Solar-diurnal variation of the horizontal force at Los Angeles, Cal. from 6¼ years of observation 1882 to 1889.

Semi-annual inequality in the Diurnal Variation of the Horizontal Force



Results of the differential measures of the horizontal intensity from observations recorded at Los Angeles, Cal.—Continued.

Another characteristic feature is the small amplitude of the diurnal variation when compared with the values observed at Philadelphia and Toronto.

The semiannual inequality in the diurnal variation is shown in the table below. It depends on the preceding table, and the values are given in scale divisions.

Diurnal variation during the summer half, during the winter half, and during the whole year, or for the six months, April to September, inclusive, the six months, October to March, inclusive, and for twelve months.

Local time.	Summer.	Winter.	Year.		Local time.	Summer.	Winter.	Year.	
			s. d.	Parts of H.				*s. d.*	Parts of H.
1^h	+1·6	+0·5	+1·0	+ ·00011	13^h	+0·3	−2·8	−1·3	− ·00014
2	+1·9	+1·1	+1·5	+ 16	14	+0·2	−1·8	−0·8	− 09
3	+2·0	+1·7	+1·9	+ 21	15	−0·5	−0·8	−0·7	− ·08
4	+2·2	+2·2	+2·2	+ 24	16	−1·5	−0·4	−0·9	− 10
5	+2·5	+2·6	+2·5	+ 27	17	−2·3	−0·2	−1·2	− 13
6	+2·5	+2·7	+2·6	+ 28	18	−2·1	−0·2	−1·2	− 13
7	+0·8	+2·7	+1·8	+ 20	19	−1·6	−0·4	−1·0	− 11
8	−1·4	+1·9	+0·3	+ 03	20	−1·2	−0·7	−0·9	− 10
9	−1·8	+0·7	−0·5	− 05	21	−0·8	−0·8	−0·8	− 9
10	−1·1	−1·1	−1·1	− 12	22	−0·4	−0·6	−0·5	− 5
11	−0·6	−2·8	−1·7	− 19	23	+0·2	−0·5	−0·1	− 1
Noon	0·0	−3·3	−1·6	− ·00017	Midn't	+1·0	+0·1	+0·5	+ .00005

This semiannual inequality is shown on the accompanying diagram (illustration No. 2), to which, for comparison, the corresponding diagram for Philadelphia, Pa., has been transferred. The construction of these diagrams depends on the difference between the annual mean and the summer and winter means for each hour of the day, as given in the above table; it therefore supposes the annual average variation to be represented by a horizontal straight line. The scale divisions were converted into parts of H.

The Philadelphia curve is taken from table, page 193, Coast Survey Report for 1862. There is much similarity between these curves. The Philadelphia curve is apparently displaced one or two hours to the right (later), with a slightly larger amplitude when compared with Los Angeles. The nodal points occur at 4.30 a. m., at 10 a. m., and again about 15^h and 21^h; at these times the respective values of the horizontal intensity will be found the same, nearly, throughout the year, hence 10 a. m. and 3 p. m. are favorable hours for absolute measures.

Principal features of the total solar diurnal variation.—The principal maximum of the horizontal force occurs at 6^h a. m. on the average throughout the year, but at $5\frac{1}{2}^h$ a. m. during the summer months and

at $6\frac{1}{2}^h$ a. m. during the winter months. Its amount is ·00029, ·00028, and ·00031 in parts of H, respectively.

The principal minimum occurs at $11\frac{1}{4}^h$ a. m. on the average throughout the year; it shifts to 9^h a. m. in summer and becomes the secondary minimum, the primary then occurring at $17\frac{1}{4}^h$. In winter the principal minimum occurs at noon, the secondary about 21^h; on the average throughout the year this last extreme is found about $17\frac{1}{2}^h$.

The maximum diurnal total range is on the average throughout the year ·00049 H, during the summer half year ·00055 H, and during the winter half year ·00066 H. The mean or average intensity of the day is reached about $8\frac{1}{3}^h$ during the year, about noon during summer, and about $9\frac{1}{3}^h$ during winter. These features are exhibited in the appended illustration (No. 3).

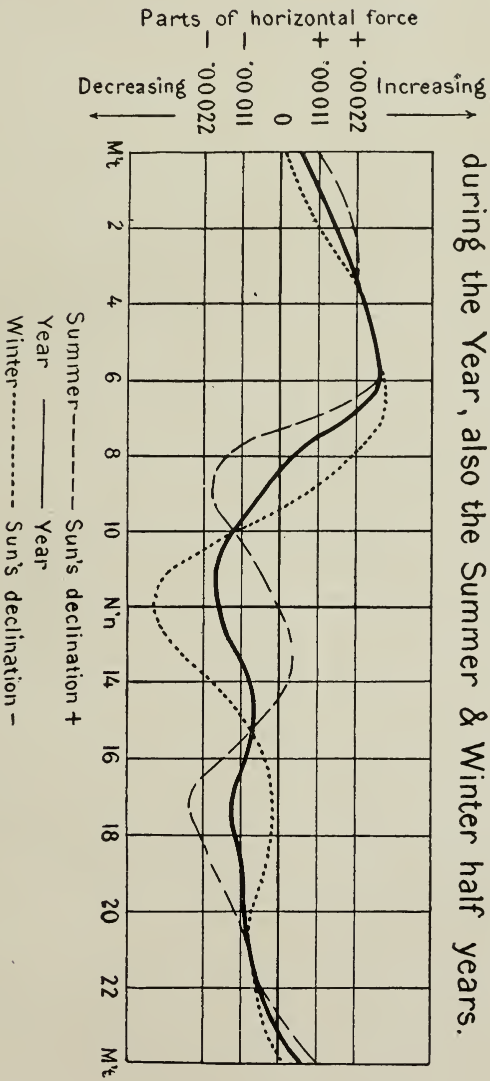
Comparative table of the diurnal variation at Los Angeles, Philadelphia, and Toronto. [*At the second station the larger disturbances have been excluded;* (p) *stands for principal and* (s) *for subordinate extreme.*]

Stations.	Morning.		Afternoon.		Total diurnal range.
	Max.	Min.	Max.	Min.	
	h.	*h.*	*h.*	*h.*	
Los Angeles, 1883–1888.	6·0	11·3	2½ (s)	5½ (s)	·00049 H.
Philadelphia,* 1840–1845.	5·7	10·9	4·0 (s)	undefined.	·00090 H.
Toronto,† 1843–1848.	6 (s)	10·5 (p)	4·1 (p)	. . .	·00155 H.

* Coast Survey Report for 1862, pp. 179 and 193.

† Magnetical and Meteorological Observations, Toronto, Can., Vol. II, London, 1853. Table XXXIII. The secondary minimum occurs about 2:30 a. m.

Long-period inequality in the total solar-diurnal variation of the horizontal force.—The dependence of the diurnal variation on the 11-year (about) or sun-spot period is shown, as in the case of the declination, in the inequality of the daily range from year to year.



Total Solar-diurnal Variation of horizontal force during the Year, also the Summer & Winter half years.

Results of the differential measures of the horizontal intensity from observations recorded at Los Angeles, Cal.—Continued.

The diurnal variation, when collected for each year separately, is exhibited in the following table, expressed in scale divisions:

[1d = ·000109H. A + sign implies that the force is greater than the mean of the day, and a — sign that it is less.]

Year.	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	Noon.
1883	+1·5	+1·8	+2·0	+2·5	+2·7	+2·9	+1·8	—0·3	—1·4	—2·2	—2·6	—2·2
1884	+1·0	+1·6	+2·0	+2·4	+2·6	+2·7	+1·7	+0·3	—0·6	—1·4	—2·5	—2·4
1885	+0·9	+1·4	+1·8	+2·2	+2·7	+2·8	+1·9	+0·4	—0·9	—1·3	—1·6	—1·6
1886	+1·3	+1·9	+1·9	+2·5	+2·8	+2·9	+2·0	+0·5	—0·2	—0·5	—0·9	—1·1
1887	+1·1	+1·5	+2·0	+2·1	+2·4	+2·4	+1·9	+0·8	+0·3	—0·3	—1·3	—1·5
1888	+0·6	+1·1	+1·7	+1·9	+2·2	+2·3	+1·4	+0·2	—0·4	—0·8	—1·4	—1·3

Year.	13h	14h	15h	16h	17h	18h	19h	20h	21h	22h	23h	Midn't.
1883	—1·5	—0·6	—0·3	—0·5	—1·1	—1·0	—0·8	—0·6	—0·4	0·0	+0·5	+0·9
1884	—1·8	—1·0	—0·7	—0·7	—1·3	—0·9	—0·8	—0·7	—0·5	—0·3	0·0	+0·5
1885	—1·1	—0·6	—0·4	—0·9	—1·1	—1·1	—1·0	—1·0	—1·0	—0·8	—0·4	+0·3
1886	—1·3	—1·3	—1·3	—1·7	—1·6	—1·7	—1·3	—0·9	—0·9	—0·6	—0·1	+0·7
1887	—1·2	—1·0	—1·0	—1·2	—1·4	—1·3	—1·1	—1·2	—0·9	—0·6	—0·4	+0·4
1888	—0·8	—0·5	—0·5	—0·7	—1·1	—0·9	—1·0	—1·0	—1·0	—0·6	—0·3	+0·3

The diurnal range for each year is as follows:

1883	5·5 *s. d.* or	·00060 in parts of H.
1884	5·2	57
1885	4·4	48
1886	4·2	46
1887	3·9	43
1888	3·7	40
Mean of six years	4·5	·00049

The maximum sun-spot activity took place in 1883, and this corresponds to the year of greatest diurnal range; the minimum activity occurred late in 1888 or early in 1889, and corresponds to the least diurnal range—between these extremes the change is systematic. For the sake of consistency the morning minimum for 1886 (— 1·3) was introduced in the place of the afternoon minimum. The ratio of the greatest to the least value of the range is as 1·5 to 1.

The variation, in direction and intensity, of the diurnal solar deflecting force acting in the plane of the horizon.—The component of the horizontal deflecting force which acts in an easterly or westerly direction, and the component at right angles to it, which acts in a northerly or southerly direction, may be combined graphically so as to exhibit the total deflecting force, producing the diurnal variation of the declination, both in direction and magnitude throughout the solar day.

To obtain the first component let θ = angle of deflection or difference in direction of the magnetic meridian at a given hour from the normal (mean of day) direction, then H$\sin\theta$ will represent the deflecting

force at that time, or sin θ will represent the same when expressed in terms of the horizontal force H. Since 1′ of arc equals $\frac{1}{3438}$ or 0·000291 of radius we need only to multiply our tabular numbers of the total solar-diurnal variation expressed in minutes by this factor, as given in Part II of this discussion. The second component for any hour is given in preceding pages, but it must be expressed in parts of H.

If in any of the accompanying diagrams we join by a straight line the point of intersection of the horizontal and vertical axes with any point or hour of the curve, that line will mark the direction of the deflecting force, and its length when measured by the intensity scale of the figure will give its intensity in terms of H. The numerals on the curves represent the hours of Los Angeles mean solar time from 0 to 24, noon being indicated by N.

The following table contains the diurnal variation of the components of the horizontal deflecting force acting on the north pole of the magnet at Los Angeles separately for each of the years 1883 to 1888, inclusive. For the east and west component a + sign indicates north end deflected towards the east, for the north and south component a + sign indicates increasing force towards the north. The tabular numbers are expressed in terms of the horizontal force H.

Results of the differential measures of the horizontal intensity from observations recorded at Los Angeles, Cal.—Continued.

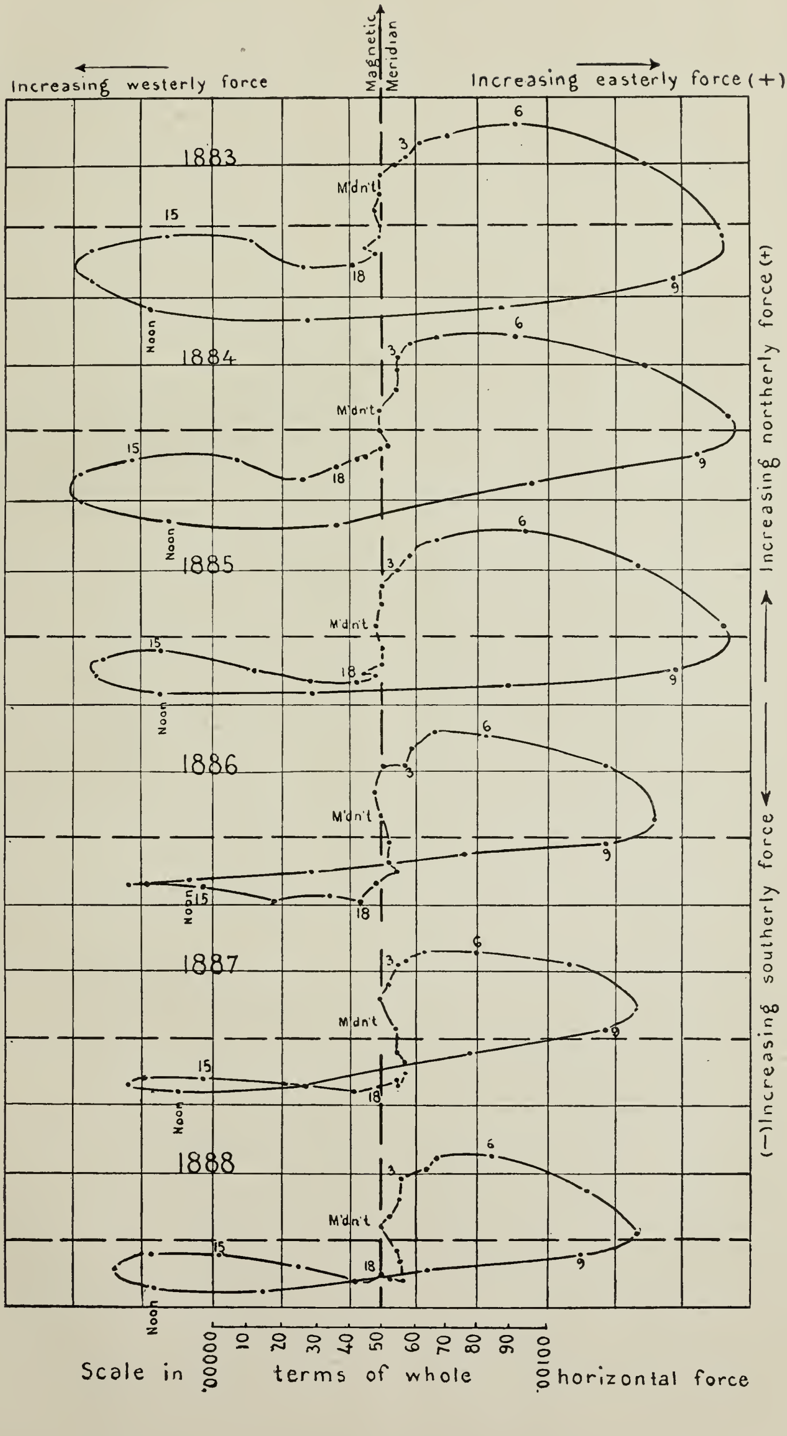
Component.	Calendar year.	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	Noon
E. and W.	1883	·00000	+·00005	+·00007	+·00012	+·00021	+·00042	+·00079	+·00102	+·00088	+·00037	—·00023	—·00067
N. and S.	1883	+ 16	+ 20	+ 22	+ 27	+ 29	+ 32	+ 20	— 003	— 15	— 24	— 28	— 24
E. and W.	1884	+ 05	+ 05	+ 05	+ 09	+ 18	+ 42	+ 79	+ 104	+ 95	+ 46	— 14	— 62
N. and S.	1884	+ 11	+ 17	+ 22	+ 26	+ 28	+ 29	+ 19	+ 003	— 07	— 15	— 27	— 26
E. and W.	1885	00	00	+ 05	+ 07	+ 18	+ 44	+ 76	+ 102	+ 88	+ 39	— 21	— 65
N. and S.	1885	+ 10	+ 15	+ 20	+ 24	+ 29	+ 31	+ 21	+ 004	— 10	— 14	— 17	— 17
E. and W.	1886	— 02	00	+ 07	+ 09	+ 18	+ 42	+ 67	+ 081	+ 67	+ 25	— 21	— 58
N. and S.	1886	+ 14	+ 21	+ 21	+ 27	+ 31	+ 32	+ 22	+ 005	— 02	— 05	— 10	— 12
E. and W.	1887	00	+ 02	+ 05	+ 07	+ 14	+ 30	+ 58	+ 076	+ 69	+ 28	— 23	— 60
N. and S.	1887	+ 12	+ 16	+ 22	+ 23	+ 26	+ 26	+ 21	+ 009	+ 03	— 03	— 14	— 16
E. and W.	1888	+ 02	+ 05	+ 05	+ 14	+ 16	+ 35	+ 62	+ 076	+ 60	+ 14	— 35	— 67
N. and S.	1888	+ 07	+ 12	+ 19	+ 21	+ 24	+ 25	+ 15	+ 002	— 04	— 09	— 15	— 14

Component.	Calendar year.	13h	14h	15h	16h	17h	18h	19h	20h	21h	22h	23h	Midnight.
E. and W.	1883	—·00083	—·00083	—·00062	—·00039	—·00023	—·00009	—·00002	—·00005	·00000	·00000	—·00002	·00000
N. and S.	1883	— 16	— 07	— 03	— 05	— 12	— 11	— 09	— 07	— 04	00	+ 05	+ 10
E. and W.	1884	— 88	— 88	— 72	— 42	— 23	— 12	— 07	— 05	00	+ 02	00	00
N. and S.	1884	— 20	— 11	— 08	— 08	— 14	— 10	— 09	— 08	— 05	— 03	00	+ 05
E. and W.	1885	— 83	— 81	— 65	— 39	— 21	— 09	— 02	— 05	— 05	00	00	+ 02
N. and S.	1885	— 12	— 07	— 04	— 10	— 12	— 12	— 11	— 11	— 11	— 09	— 04	+ 03
E. and W.	1886	— 74	— 69	— 53	— 32	— 16	— 07	— 02	+ 05	+ 05	+ 02	+ 02	00
N. and S.	1886	— 14	— 14	— 14	— 19	— 17	— 19	— 14	— 10	— 10	— 07	— 01	+ 08
E. and W.	1887	— 74	— 69	— 51	— 28	— 09	00	+ 05	+ 05	+ 07	+ 07	+ 05	+ 05
N. and S.	1887	— 13	— 11	— 11	— 13	— 15	— 14	— 12	— 13	— 10	— 07	— 04	+ 04
E. and W.	1888	— 79	— 67	— 49	— 25	— 09	00	+ 02	+ 07	+ 07	+ 05	+ 05	00
N. and S.	1888	— 09	— 05	— 05	— 08	— 12	— 10	— 11	— 11	— 11	— 07	— 03	+ 03

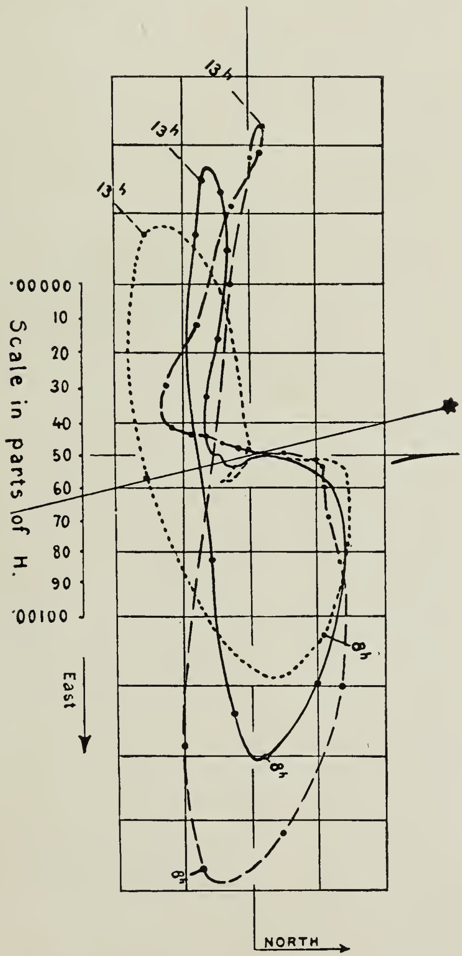
The most striking features of this diagram (illustration No. 4) are the weakness, approaching disappearance, of the deflecting force about midnight or between the hours 18 and 3, and the gradual decline in the deflecting force from the year of greatest activity of the sun in producing sun spots to the year of least activity.

The greatest deflecting force exceeds but little the one-thousandth part of the horizontal force.

The following diagram (illustration No. 5) exhibits the *annual inequality* in the diurnal variation of the horizontal deflecting force. The full line curve refers to the diurnal action of the force on the average throughout the year, or, more precisely, to the mean of six years; the broken curve refers to the force acting during the six months when the sun has north declination, or from April to September, *i. e.*, during the summer half year; and the dotted curve refers to the six months when the sun has south declination, or from October to March, *i. e.*, during the winter half year.



Diurnal variation in direction and magnitude of the horizontal deflecting force at Los Angeles in the years 1883–'88.



Annual inequality of the
solar deflecting force.

Results of the differential measures of the horizontal intensity from observations recorded at Los Angeles, Cal.—Continued.

		1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	Noon.
E. and W.	Year.	+ ·00001	+ ·00003	+ ·00006	+ ·00010	+ ·00018	+ ·00039	+ ·00070	+ ·00090	+ ·00078	+ ·00032	— ·00023	— ·00063
N. and S.	Year.	+ 11	+ 16	+ 21	+ 24	+ 27	+ 28	+ 20	+ 3	— 5	— 12	— 19	— 17
E. and W.	Apr. to Sept.	+ 1	+ 4	+ 10	+ 19	+ 33	+ 70	+ 113	+ 124	+ 87	+ 10	— 50	— 86
N. and S.	Apr. to Sept.	+ 17	+ 21	+ 22	+ 24	+ 27	+ 27	+ 9	— 15	— 20	— 12	— 7	0
E. and W.	Oct. to Mar.	+ 1	+ 1	+ 1	+ 1	+ 2	+ 8	+ 26	+ 55	+ 67	+ 51	+ 7	— 40
N. and S.	Oct. to Mar.	+ 5	+ 12	+ 19	+ 24	+ 28	+ 29	+ 29	+ 21	+ 8	— 12	— 31	— 36

		13h	14h	15h	16h	17h	18h	19h	20h	21h	22h	23h	Midnight.
E. and W.	Year.	— ·00080	— ·00076	— ·00059	— ·00034	— ·00017	— ·00006	·00000	·00000	+ ·00002	+ ·00003	+ ·00002	·00000
N. and S.	Year.	— 14	— 9	— 8	— 10	— 13	— 13	— 11	— 10	— 9	— 5	— 1	+ 5
E. and W.	Apr. to Sept.	— 95	— 88	— 72	— 38	— 20	— 9	— 7	— 7	— 4	— 2	0	0
N. and S.	Apr. to Sept.	+ 3	+ 2	— 6	— 16	— 25	— 23	— 17	— 13	— 9	— 4	+ 2	+ 10
E. and W.	Oct. to Mar.	— 63	— 63	— 48	— 29	— 11	— 1	+ 6	+ 8	+ 9	+ 8	+ 5	+ 1
N. and S.	Oct. to Mar.	— 31	— 20	— 9	— 4	— 2	— 2	— 4	— 8	— 9	— 7	— 5	+ 1

On the preceding diagram the true meridian is indicated by a star; the magnetic meridian by a half arrowhead.

Separation and analysis of the larger disturbances of the horizontal force.—The treatment followed in the investigation of the disturbances exhibited in the hourly ordinates of the photographic traces, after they had been reduced to a uniform temperature of the bifilar magnet, was the same as that pursued for the tabulated hourly ordinates of the declination traces. The value of the mean error, m, or the average deviation of an observation from its monthly mean for the respective hour, was found by means of the extreme range of the values as follows: For the year 1883, the ranges were taken for the odd hours of the 1st, 3d, 5th, etc., month, and for the even hours for the 2d, 4th, etc., month; for the year 1888, the order was reversed. The values so obtained, viz, $m=\frac{1}{5}$ range, were found to answer quite well; they are, for the respective months—

														d.
In 1883,	2·6	5·8	4·8	6·7	4·2	4·7	6·2	5·1	8·6	4·5	7.2	3·9	Mean of 12 months	±5·4
In 1888,	4·2	2·5	3·7	3·8	4·8	3·1	2·7	3·8	3·4	3·4	3·0	2·6	Mean of 12 months	±3·4
Mean adopted for whole six-year series,														$m=\pm 4{\cdot}4$

which refers to the middle of the eleven-year cycle.

According to Dr. Lloyd's rule 1·5 m would be the limit of separation, but 1·9 m to 2 m was preferred, as in the case of the disturbances in the declination; hence a trial was given making 8 scale divisions the limit, that is, any observation differing more than 8 scale divisions from its respective monthly mean was considered as belonging to the class of (large) disturbances; finally the limit adopted was 9 divisions. Nine scale divisions equal 0·00098 in parts of the horizontal force, or 0·000268 of a dyne.

At Philadelphia the limit adopted* was 33 scale divisions, or 0·00120 in parts of H; it marked, as a disturbance, 1 in 14 observations on the average.

At Toronto the limit adopted† was 14 scale divisions, or 0·00120 H; it separated, on the average, 1 in 12½ observations.

In his discussion of the disturbances observed in 1888, at Parc Saint Maur, Mr. Moureaux takes 0·00020 H, an arbitrary limit for a disturbance.

Owing to certain unsatisfactory features of the record for one month at the beginning and for several at the end of the series, the investigation of the disturbances is here confined to the hourly record of the six years 1883 to 1888, inclusive.

In the tables of hourly ordinates taken from the bifilar traces and reduced to a standard temperature of the magnet any value differing more than nine divisions from the monthly mean value of its re-

* Coast Survey Report for 1862, pp. 174, 175. One division of scale was 0·0000365 H.

† Volume III of the Toronto Meteorological and Magnetic Observations (Sabine). One division of scale = 0·0000860 H.

Results of the differential measures of the horizontal intensity from observations recorded at Los Angeles, Cal.—Continued.

spective hour was marked by an asterisk. New hourly means were then taken for each month, omitting all marked values. These new means are given at the foot of each monthly table, and they constitute the hourly *normals* for the month. No notice was taken of the few interpolated values inclosed between rectangular brackets, so far as disturbances are concerned. The total number of hourly values is 52 560, and the total number of disturbed values 3 231; hence our limit indicates, on the average, one large disturbance in every sixteen observations.**

In what follows the disturbances will be classified with respect to numbers, magnitude, and whether increasing or diminishing the normal horizontal intensity. One scale division equals 0·000109 H, and H = 0·2728 of a dyne, nearly.

Long-period inequality in the disturbances of the horizontal component of the magnetic force.

Year.	No. of disturbances.			Ratio to mean.	Aggregate amount.			Ratio to mean.	Average magnitude.		
	Incr.	Decr.	Total.		Incr.	Decr.	Total.		Incr.	Decr.	Total.
					d.	*d.*	*d.*		*d.*	*d.*	*d.*
1883	252	648	900	1·67	3012	10299	13311	1·72	12·0	15·9	14·8
1884	97	398	495	0·92	1085	6281	7366	0·95	11·2	15·8	14·9
1885	100	476	576	1·07	1184	7154	8338	1·07	11·8	15·0	14·5
1886	113	484	597	1·11	1259	7613	8872	1·14	11·1	15·7	14·9
1887	60	290	350	0·65	706	3924	4630	0·60	11·8	13·5	13·2
1888	81	232	313	0·58	895	3148	4043	0·52	11·0	13·6	12·9
Total	703	2528	3231		8141	38419	46560		Mean 11·5	14·9	14·2

The progressive diminution in the number and aggregate amount of the disturbances in the horizontal plane is seen to follow the sun-spot cycle, and the ratio, for number and amount, for the year of greatest solar activity (1883) as compared with the year preceding that of least activity (1889) is nearly as 3·1 to 1; and the same law holds for increasing as well as for decreasing disturbances of the horizontal intensity. It also appears that the average magnitude of an increasing disturbance (11·5 scale divisions) is less variable in the 11⅓-year cycle than that of a decreasing disturbance.

At Philadelphia the dependence of the disturbances on the solar cycle is shown by the minimum amount recorded for the year July, 1843, to July, 1844,† and the same is shown at Toronto by the ratios expressing the relative amount of disturbances in each year, viz: the

** The marking of the disturbed values and the computation of the hourly normals are due to Mr. L. A. Bauer.

† See table x, pp. 182, 183, of Coast Survey Report for 1862.

minimum in 1844 for decreasing force, and in 1845 for increasing force.** The sun-spot minimum occurred in 1843, with but little change in 1844.

Ratio of increasing to decreasing disturbances.—In every one of the six years of record at Los Angeles the disturbances increasing the force were smaller in number and less in magnitude than those decreasing the force, the average ratio being 1 to 3·6 for the numbers, and 1 to 4·7 for the magnitudes. For Philadelphia † these ratios were 1 to 1·8 and 1 to 1·2, respectively, but for Toronto the last ratio was 1 to 6·4 for the years 1844 to 1848. ‡

Annual inequality in the disturbances of the horizontal force.—The following two tables exhibit the number and aggregate amount of the disturbances for each month of the years 1883 to 1888, inclusive, and for increasing and decreasing disturbances separately.

Month.	Number of disturbances.			Ratio to mean.	Aggregate amount.			Ratio to mean at—		Average magnitude.		
	Incr.	Decr.	Total.		Incr.	Decr.	Total.	Los Angeles.	Toronto.*	Incr.	Decr.	Total.
					d.	d.	d.			d.	d.	d.
Jan.	45	169	214	0·80	504	2400	2904	0·75	0·58	11·2	14·2	13·6
Feb.	23	158	181	0·67	239	2308	2547	0·66	0·94	10·4	14·6	14·1
Mar.	47	277	324	1·20	545	4722	5267	1·36	0·94	11·6	17·1	16·3
Apr.	50	274	324	1·20	608	4011	4619	1·19	1·50	12·2	14·6	14·3
May	71	244	315	1·17	855	3866	4721	1·22	0·90	12·0	15·8	15·0
June	64	163	227	0·84	738	2284	3022	0·78	0·36	11·5	14·0	13·3
July	56	152	208	0·77	669	2305	2974	0·77	0·61	12·0	15·2	14·3
Aug.	88	186	274	1·02	1072	2546	3618	0·93	0·75	12·2	13·7	13·2
Sept.	140	332	472	1·75	1615	5285	6900	1·78	1·71	11·5	15·9	14·6
Oct.	44	213	257	0·96	472	3115	3587	0·92	1·48	10·7	14·8	14·0
Nov.	47	234	281	1·04	501	3892	4393	1·13	0·98	10·7	16·6	15·6
Dec.	28	126	154	0·57	323	1685	2008	0·52	1·28	11·5	13·4	13·0

In looking over the monthly distribution of the disturbances we find those which decrease the horizontal component to be, in all cases, more numerous and of greater extent than those which increase the force. The same law was found to hold for the observations made at Philadelphia (1840–'45).†

The distribution of the disturbances in number and aggregate amount throughout the year exhibits a double progression, with maxima in March and September, or about the equinoxes, and with minima in December and July, or about the solstices. The September maximum exceeds the December minimum in the proportion of 3·25 to 1·00.

This annual inequality in the disturbances presents itself with great distinctness at Los Angeles, as may be seen by comparison with the

** See table VIII of Abstracts and results of magnetical, etc., observations at the observatory at Toronto from 1841 to 1871, Toronto, 1875.

† Tables XI and XII; Coast Survey Report for 1862.

‡ Walker's Terr. & Cos. Magn., Cambridge, 1866, p. 274.

Results of the differential measures of the horizontal intensity from observations recorded at Los Angeles, Cal.—Continued.

results at Toronto* and at Philadelphia; at the latter place it was so hidden by irregularities as to be almost unrecognizable.†

Respecting the magnitude of the disturbances the monthly average values appear irregularly distributed over the year, though with a slight indication of larger developments in March and September and a less one in December. In Part II of this discussion it has been shown that the annual distribution of the disturbances in declination, with respect to their average magnitude, is an indifferent one, which is similar to the case of the disturbances in the horizontal component of the force.

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*Walker, Terr. and Cos. Mag'm, p. 276, series 1844–'48.

†Coast Survey Report for 1862, p. 183.

The diurnal inequality in the disturbances of the horizontal component of the magnetic force.

[The tabular values depend on the hourly co-ordinates for the six years, 1883 to 1888, inclusive.]

Local hours.	No. of disturbances.			Ratio to mean values.			Aggregate amount.			Ratio to mean values.			Average magnitude.	
	Incr.	Decr.	Excess of decr.	Incr.	Decr.	All.	Incr.	Decr.	Excess of decr.	Incr.	Decr.	All.	Incr.	Decr.
							d.	d.	d.				d.	d.
1	18	79	61	0·61	0·75	0·72	216	1169	953	0·64	0·73	0·71	12·0	14·8
2	18	67	49	0·61	0·64	0·63	247	939	692	0·73	0·59	0·61	13·7	14·0
3	16	53	37	0·55	0·50	0·51	175	765	590	0·52	0·48	0·48	10·9	14·4
4	10	40	30	0·34	0·38	0·37	126	533	407	0·37	0·33	0·34	12·6	13·3
5	17	33	16	0·58	0·31	0·37	191	473	282	0·56	0·30	0·34	11·2	14·3
6	22	44	22	0·75	0·42	0·49	247	595	348	0·73	0·37	0·43	11·2	13·5
7	23	45	22	0·78	0·43	0·51	264	622	358	0·78	0·39	0·46	11·5	13·8
8	36	46	10	1·23	0·44	0·61	434	680	246	1·28	0·42	0·57	12·1	14·8
9	42	87	45	1·43	0·83	0·96	515	1134	619	1·52	0·71	0·85	12·3	13·0
10	55	90	35	1·88	0·85	1·08	648	1266	618	1·91	0·79	0·99	11·8	14·1
11	60	110	50	2·05	1·04	1·26	710	1561	851	2·09	0·98	1·17	11·8	14·2
Noon	63	126	63	2·15	1·20	1·40	720	1726	1006	2·12	1·08	1·26	11·4	13·7
13	56	117	61	1·91	1·12	1·29	637	1707	1070	1·88	1·07	1·21	11·4	14·6
14	46	132	86	1·57	1·25	1·32	548	1896	1348	1·62	1·18	1·26	11·9	14·4
15	37	148	111	1·26	1·41	1·37	398	2164	1766	1·17	1·35	1·32	10·8	14·6
16	27	143	116	0·92	1·36	1·26	312	2326	2014	0·92	1·45	1·36	11·6	16·3
17	22	176	154	0·75	1·67	1·47	242	2737	2495	0·71	1·71	1·54	11·0	15·6
18	22	190	168	0·75	1·80	1·58	236	2951	2715	0·70	1·84	1·64	10·7	15·5
19	16	166	150	0·55	1·58	1·35	185	2827	2642	0·55	1·77	1·55	11·6	17·0
20	21	171	150	0·72	1·62	1·43	244	2776	2532	0·72	1·74	1·56	11·6	16·2
21	14	140	126	0·48	1·33	1·14	154	2300	2146	0·45	1·44	1·26	11·0	16·4
22	16	131	115	0·55	1·24	1·09	173	2166	1993	0·51	1·35	1·21	10·8	16·5
23	20	107	87	0·68	1·02	0·94	235	1737	1502	0·69	1·09	1·02	11·8	16·2
Midnight	26	87	61	0·89	0·83	0·84	284	1369	1085	0·84	0·86	0·85	10·9	15·7
Total	703	2528	1825				8141	38419	30278					

Results of the differential measures of the horizontal intensity from observations recorded at Los Angeles, Cal.—Continued.

From the contents of the preceding table we conclude that:

(1) The distribution of the disturbances in a solar day is of a periodic character.

(2) The disturbances which *increase* the horizontal force are most active at noon and least active at 4^h a. m.

(3) The disturbances which *decrease* the horizontal force are most active at 18^h or six hours after noon and least so at 5^h a. m. The earth, therefore, makes a quarter of a revolution between the times of extreme development of the increasing and the decreasing forces.

(4) If we keep in view the *aggregate amount* of the disturbances, instead of their number of occurrence, we find the above laws to hold likewise.

(5) The *ratio* between the daily maximum and minimum is 6·0 to 1 for the increasing forces and 6·0 to 1 also for the decreasing forces.

(6) The number and average amount of the disturbances *decreasing* the horizontal force is at all hours of the day greater than for disturbances increasing the same, and the excess of the former over the latter is greatest at 18^h and least at 8^h.

(7) The average *magnitude* of the disturbances *increasing* the force appears to be the same at all hours, whereas the average magnitude of those *decreasing* the force exhibit an increase between the hours 4 p. m. and 2 a. m.

Comparison of the above results with similar ones obtained at other stations: Respecting the diurnal periodicity of the disturbances, the comparative table for Kew (seven-year series, 1858–'64), for Toronto (five-year series, 1844–'48), for Philadelphia (five-year series, 1840–'45), and for Los Angeles is quite instructive, and makes it clear that the results at many more stations will have to be collected before a comprehensive knowledge can be had of the laws of action of the disturbances even for the limited area of the United States.

Hours (counting from midnight to midnight 0 to 24^h) of the day of occurrence of extreme values.

Locality.	Disturbances increasing force.		Disturbances decreasing force.	
	Max.	Min.	Max.	Min.
Kew.	17^h	6^h	10^h and 23^h	17^h
Toronto.	16	2	2 and 7	16
Philadelphia.	12	6	20 and (10?)	4
Los Angeles.	12	4	18	5

We notice a fair accord of the disturbance periodicity for Philadelphia and Los Angeles, but a discord in the hours for Kew and Toronto. The complexity of the phenomenon is moreover brought more fully into

view by the exhibit of a double progression of the *decreasing* force inequality at Kew, which double wave is feebly represented at Toronto and obscurely indicated at Philadelphia, but which has no existence at Los Angeles. It is also noteworthy that at the two southern stations, St. Helena and the Cape, the maximum in the disturbances which *increase* the force occurs at 11^h, thus agreeing with Los Angeles and Philadelphia. Likewise we find the same accord for the maximum of those *decreasing* the force, which occurs between 18^h and 19^h.

At all the stations named the disturbances *decreasing* the force preponderate over those which increase it. The ratio for the horizontal force disturbances for Toronto is 6·4 to 1 (as stated); for Kew it is as 3·2 to 1.

The normal solar diurnal variation of the horizontal component of the force.—In the following table I have collected the hourly normals, as given at the foot of the monthly tabulation of the hourly coordinates, all referred to the standard temperature of the bifilar magnet. These normals are simply the new means after the exclusion of all values marked as disturbances and condensed from a six-year series into a one-year series. The second table, headed "Normal solar-diurnal variation," is derived from the first by subtracting the respective monthly mean from each hourly mean and converting the scale divisions into parts of the horizontal force. A + sign signifies a force greater than that of the mean of the day, a − sign one less than this mean.

DIFFERENTIAL OBSERVATIONS OF THE HORIZONTAL

Mean hourly values (after rejection of the larger disturbances) of the solar-sive, expressed in

[Local mean time. 200 scale divisions + tabular quantity; all

Years.	Month.	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	Noon
1883 to 1888, inclusive.	Jan.	99·0	99·2	99·7	100·3	101·0	101·[illegible]	101·9	101·7	100·8	97·2	93·4	93·1
	Feb.	99·7	100·3	101·0	101·5	101·8	102·3	102·6	102·9	102·0	100·8	98·8	97·4
	Mar.	101·7	102·4	102·9	103·2	102·9	102·8	102·5	100·8	99·7	99·0	98·2	97·4
	Apr.	103·1	103·4	103·7	104·0	104·3	104·6	102·9	101·1	100·2	99·8	99·4	99·6
	May	105·0	105·2	104·8	104·5	105·0	105·0	103·8	102·2	102·3	102·9	103·2	103·6
	June	104·2	104·2	104·5	104·5	104·9	105·0	103·9	102·3	102·4	103·7	104·7	105·1
	July	101·9	102·2	102·1	102·2	102·5	102·8	101·4	99·0	98·7	99·6	100·7	101·8
	Aug.	100·2	100·2	100·3	100·5	100·6	100·3	98·0	95·1	95·2	96·3	97·0	98·1
	Sept.	96·3	96·7	97·1	97·4	96·9	96·8	94·3	91·1	90·6	91·4	91·9	92·6
	Oct.	92·0	92·6	93·2	93·5	93·5	93·2	92·2	89·6	88·2	87·7	88·4	88·6
	Nov.	89·3	89·8	90·0	90·4	90·7	91·1	90·9	90·1	88·6	86·8	85·7	86·1
	Dec.	86·8	87·3	88·1	88·4	89·2	89·6	90·2	90·2	89·2	86·8	84·0	82·9

Normal solar-diurnal variation of the horizontal force at Los

[Local mean time. a { + − sign indicates a force

Years.	Month.	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	Noon
1883 to 1888, inclusive.	Jan.	+0·4	+0·6	+1·1	+1·7	+2·4	+2·8	+3·3	+3·1	+2·2	−1·4	−5·2	−5·5
	Feb.	−0·1	+0·5	+1·2	+1·7	+2·0	+2·5	+2·8	+3·1	+2·2	+1·0	−1·0	−2·4
	Mar.	+0·9	+1·6	+2·1	+2·4	+2·1	+2·0	+1·7	0·0	−1·1	−1·8	−2·6	−3·4
	Apr.	+1·1	+1·4	+1·7	+2·0	+2·3	+2·6	+0·9	−0·9	−1·8	−2·2	−2·6	−2·4
	May	+1·6	+1·8	+1·4	+1·1	+1·6	+1·6	+0·4	−1·2	−1·1	−0·5	−0·2	+0·2
	June	+0·9	+0·9	+1·2	+1·2	+1·6	+1·7	+0·6	−1·0	−0·9	+0·4	+1·4	+1·8
	July	+1·4	+1·7	+1·6	+1·7	+2·0	+2·3	+0·9	−1·5	−1·8	−0·9	+0·2	+1·3
	Aug.	+1·9	+1·9	+2·0	+2·2	+2·3	+2·0	−0·3	−3·2	−3·1	−2·0	−1·3	−0·2
	Sept.	+1·8	+2·2	+2·6	+2·9	+2·4	+2·3	−0·2	−3·4	−3·9	−3·1	−2·6	−1·9
	Oct.	+0·9	+1·5	+2·1	+2·4	+2·4	+2·1	+1·1	−1·5	−2·9	−3·4	−2·7	−2·5
	Nov.	+0·7	+1·2	+1·4	+1·8	+2·1	+2·5	+2·3	+1·5	0·0	−1·8	−2·9	−2·5
	Dec.	−0·3	+0·2	+1·0	+1·3	+2·1	+2·5	+3·1	+3·1	+2·1	−0·3	−3·1	−4·2

COMPONENT OF THE MAGNETIC FORCE.

diurnal variation for each month from the 6 years, 1883 to 1888, inclu-
scale divisions.

readings are reduced to standard temperature of bifilar magnet.]

13h	14h	15h	16h	17h	18h	19h	20h	21h	22h	23h	Midn't.	Daily mean.
93·8	96·2	98·0	98·9	99·0	99·6	99·1	98·9	98·4	98·4	98·5	98·6	98 6
97·5	97·5	97·8	98·4	98·8	99·5	99·1	99·0	99·0	98·9	99·2	99·2	99·8
97·9	99·7	100·8	101·0	101·2	100·6	100·6	100·6	100·7	100·7	100·8	101·5	100·8
100·4	101·1	102·2	102·2	101·7	101·6	101·6	101·8	101·7	102·6	102·6	102·5	102·0
104·2	103·9	103·0	101·6	101·3	101·2	102·2	102·3	102·6	102·8	103·9	104·3	103·4
104·8	104·4	103·0	101·4	100·2	100·5	100·9	101·7	102·2	103·1	103·2	103·6	103·3
101·9	101·1	100·2	98·4	97·6	98·1	97·5	99·9	100·1	100·6	101·0	101·5	100·5
98·8	98·5	97·8	96·8	96·5	97·5	98·2	98·5	98·4	98·7	98·9	99·9	98·3
93·0	93·9	94·8	94·8	94·6	95·0	94·8	95·2	94·5	94·1	94·6	95·3	94·5
89·9	90·4	91·1	91·2	91·7	91·2	91·4	91·4	90·9	91·0	91·0	91·8	91·1
86·2	86·4	87·4	88·4	88·8	89·2	88·9	88·0	88·3	88·5	88·1	88·7	88·6
83·1	84·7	86·2	87·4	88·0	87·8	87·3	86·6	86·3	86·4	86·1	86·6	87·1

Angeles, Cal., between 1883 and 1888, expressed in scale divisions.

{ greater / smaller } than the average value of H.]

13h	14h	15h	16h	17h	18h	19h	20h	21h	22h	23h	Midn'
—4·8	—2.4	—0·6	+0·3	+0·4	+1·0	+0·5	+0·3	—0·2	—0·2	—0·1	0·0
—2·3	—2·3	—2·0	—1·4	—1·0	—0·3	—0·7	—0·8	—0·8	—0·9	—0·6	—0·6
—2·9	—1·1	0·0	+0·2	+0·4	—0·2	—0·2	—0·2	—0·1	—0·1	0·0	+0·7
—1·6	—0·9	+0·2	+0·2	—0·3	—0·4	—0·4	—0·2	—0·3	+0·6	+0·6	+0·5
+0·8	+0·5	—0·4	—1·8	—2·1	—2·2	—1·2	—1·1	—0·8	—0·6	+0·5	+0·9
+1·5	+1·1	—0·3	—1·9	—3·1	—2·8	—2·4	—1·6	—1·1	—0·2	—0·1	+0·3
+1·4	+0·6	—0·3	—2·1	—2·9	—2·4	—3·0	—0·6	—0·4	+0·1	+0·5	+1·0
+0·5	+0·2	—0·5	—1·5	—1·8	—0·8	—0·1	+0·2	+0·1	+0·4	+0·6	+1·6
—1·5	—0·6	+0·3	+0·3	+0·1	+0·5	+0·3	+0·7	0·0	—0·4	+0·1	+0·8
—1·2	—0·7	0·0	+0·1	+0·6	+0·1	+0·3	+0·3	—0·2	—0·1	—0·1	+0·7
—2·4	—2·2	—1·2	—0·2	+0·2	+0·6	+0·3	—0·6	—0·3	—0·1	—0·5	+0·1
—4·0	—2·4	—0·9	+0·3	+0·9	+0·7	+0·2	—0·5	—0·8	—0·7	—1·0	—0·5

DIFFERENTIAL OBSERVATIONS OF THE HORIZONTAL

Normal solar-diurnal variation of the horizontal force at Los Angeles,

[Local mean time. a {+ − indicates a force

	Month.	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	Noon
Means	Feb. Mar. Apr.	+0·6	+1·2	+1·7	+2·0	+2·1	+2·4	+1·8	+0·7	−0·2	−1·0	−2·1	−2·7
	May June July	+1·3	+1·5	+1·4	+1·3	+1·7	+1·9	+0·6	−1·2	−1·3	−0·3	+0·5	+1·1
	Aug. Sept. Oct.	+1·5	+1·9	+2·2	+2·5	+2·4	+2·1	+0·2	−2·7	−3·3	−2·8	−2·2	−1·5
	Nov. Dec. Jan.	+0·3	+0·7	+1·2	+1·6	+2·2	+2·6	+2·9	+2·6	+1·4	−1·2	−3·7	−4·1

COMPONENT OF THE MAGNETIC FORCE—Continued.

Cal., between 1883 and 1888, expressed in scale divisions—Continued.

{greater / smaller} than the average value of H.]

13^h	14^h	15^h	16^h	17^h	18^h	19^h	20^h	21^h	22^h	23^h	Midn't.
-2·3	—1·4	—0·6	—0·3	—0·3	—0·3	—0·4	—0·4	—0·4	—0·1	0·0	+0·2
+1·2	+0·7	—0·3	—1·9	—2·7	—2·5	—2·2	—1·1	—0·8	—0·2	+0·3	+0·7
—0·7	—0·4	—0·1	—0·4	—0·4	—0·1	+0·2	+0·4	0·0	0·0	+0·2	+1·0
—3·7	—2·3	—0·9	+0·1	+0·5	+0·8	+0·3	—0·3	—0·4	—0·3	—0·5	—0·1

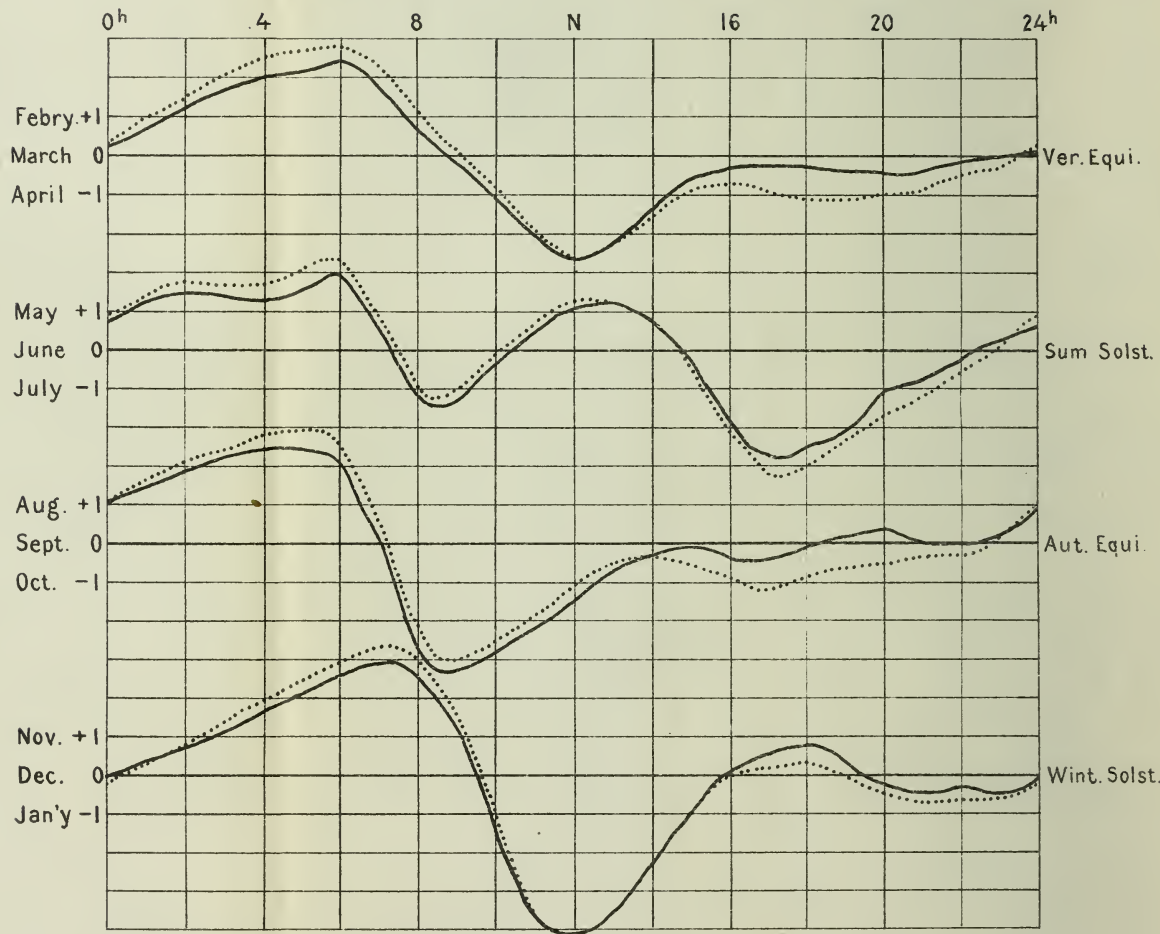
	Month.	Daily range. Div's.	Daily range. Parts of H.
Means	Feb. Mar. Apr.	5·1	0·00056
	May June July	4·6	50
	Aug. Sept. Oct.	5·8	63
	Nov. Dec. Jan.	7·0	76

The following table of the "Total solar-diurnal variation" is given here for a direct comparison of the diurnal variations, inclusive and exclusive of the larger disturbances; it refers to the same combination of months, hence excludes the months of December, 1882, and January and February, 1889:

Means.	1^h	2^h	3^h	4^h	5^h	6^h	7^h	8^h	9^h	10^h	11^h	Noon.
Feb., Mar., Apr.	+1·0	+1·5	+2·1	+2·5	+2·7	+2·8	+2·3	+1·2	+0·1	−0·8	−1·9	−2·7
May, June, July	+1·4	+1·8	+1·7	+1·7	+2·1	+2·3	+0·9	−0·9	−1·0	−0·1	+0·7	+1·3
Aug., Sept., Oct.	+1·7	+2·1	+2·4	+2·8	+2·9	+2·6	+0·7	−2·1	−3·0	−2·5	−1·8	−1·1
Nov., Dec., Jan.	+0·3	+0·8	+1·4	+2·0	+2·5	+3·0	+3·3	+3·0	+1·7	−0·9	−3·7	−4·2

Means.	13^h	14^h	15^h	16^h	17^h	18^h	19^h	20^h	21^h	22^h	23^h	Midn't.
Feb., Mar., Apr.	−2·3	−1·6	−0·9	−0·8	−0·9	−1·1	−1·1	−1·0	−0·9	−0·5	−0·3	+0·3
May, June, July	+1·2	+0·8	−0·5	−2·1	−3·2	−3·0	−2·4	−1·7	−1·2	−0·6	+0·1	+0·9
Aug., Sept., Oct.	−0·5	−0·4	−0·6	−0·9	−1·2	−0·8	−0·6	−0·5	−0·3	−0·3	+0·2	+1.1
Nov., Dec., Jan.	−3 6	−2·3	−0·8	0·0	+0·2	+0·3	0·0	−0·5	−0·7	−0·6	−0·6	−0·2

Means.	Daily range. Div's.	Daily range. In parts of H.
Feb., Mar., Apr.	5·5	0·00060
May, June, July	5·5	0·00060
Aug., Sept., Oct.	5·9	0·00064
Nov., Dec., Jan.	7·5	0·00082



Total solar-diurnal variation of H, from all observations. ....

Normal " " " " ", larger disturbances excluded ————

Results of the differential measures of the horizontal intensity from observations recorded at Los Angeles, Cal.—Continued.

The influence of the larger disturbances on the diurnal variation is best shown by means of the accompanying diagrams (illustration No. 6), combining three months each, namely, two having an equinoctial month for its middle and two having a solstitial month for its middle. It would appear that about the equinoxes the diurnal variation exhibits but one maximum and one minimum, whereas about the solstices, and particularly at the summer solstice, it shows two maxima and two minima. In all cases the exclusion of the disturbances leaves the general character of the curves unchanged, but diminishes the daily amplitude. This diminution of the range is greatest for the three months including the summer solstice, viz: From 5·5 divisions or 0·00060 in parts of H to 4·6 divisions or 0·00050 in parts of H, that is, one-sixth of the whole range.

As has already been noticed the exclusion of the disturbances would have the general effect of raising the absolute value of the horizontal force.

DAYS OF LARGE DISTURBANCES IN THE HORIZONTAL COMPONENT OF THE FORCE.

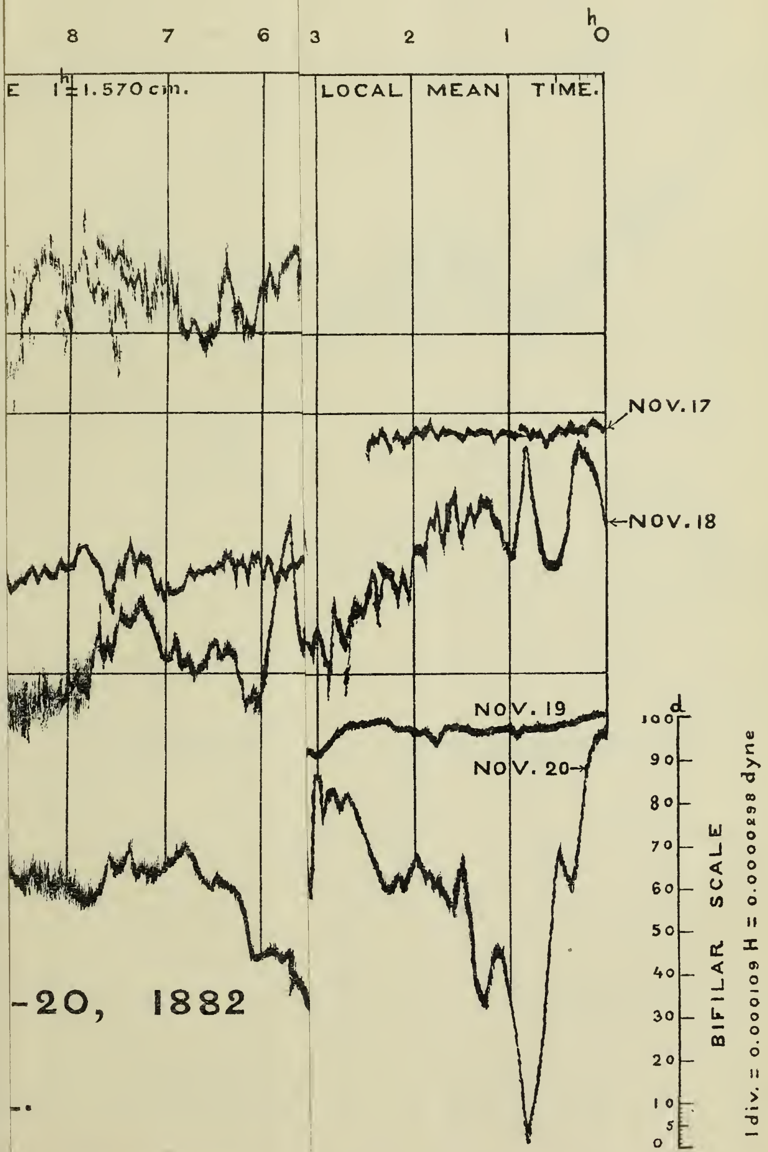
The following table contains the dates on which the bifilar curves show large disturbances. A range of 30 scale divisions or upwards on any one day was taken as a disturbed day. A range of 15′ in declination change (adopted in Part II) would correspond to 0·00436 in parts of the horizontal force or to 40 scale divisions of the bifilar instrument; the limit of 30 divisions or 0·00327 H has been preferred however, as this includes very nearly all days on which the declination was disturbed. The reduction to standard temperature has been applied. The table is arranged similarly to that given in Part II. The hours are counted from midnight (0) to 24 hours, and increasing scale divisions correspond to increasing force.

Days of large disturbance in the horizontal component of the force at Los Angeles, Cal., October, 1882, to February, 1889.

[An asterisk (*) indicates day of large disturbance in declination.]

Date.	Local mean time of extremes.		Extreme scale readings. 200*d*.+		Range of day in terms of H.	Magnitude of disturbance or difference from normal in terms of H.	
	Greatest force.	Least force.	Max.	Min.		Max.	Min.
1882.	*h. m.*	*h. m.*	*d.*	*d.*			
Oct. 2*	2 25	11 05	163 (?)	86 (?)	·0084	+ ·0035	— ·0042
Oct. 5*	3 45	20 10	147	88	64	17	45
Oct. 6	3 30	1 15	144	112	35	14	20
Oct. 23	21 55	21 30	153	112	45	26	18
Oct. 24	19 15	21 30	143	112	34	15	18
Oct. 27	22 15	17 30	146	111	38	18	18
Nov. 11	22 55	24 00	149	116	36	23	15
Nov. 12*	5 35	21 45	142	81	66	14	51
Nov. 13*	5 00	8 30	134	87	51	06	41
Nov. 14	19 50	11 10	141	103	41	12	21
Nov. 17*†	3 00	20 10	148 (?)	4	157 (?)	+ 23 (?)	137
Nov. 18*†	2 55	11 00	125	69	061	— 02	058
Nov. 19*†	13 50	20 50	124	34	98	+ 01	104
Nov. 20*†	0 50	4 15	148	59	97	+ 22	075
Nov. 21	22 35	9 00	120	73	51	— 08	57
Nov. 25	8 30	16 15	129	97	35	+ 04	34
Dec. 15	16 00	23 45	153	116	40	25	16
Dec. 18	22 05	20 15	144	109	38	15	23
Dec. 20*	7 30	4 50	149	88	66	16	48
1883.							
Jan. 26	2 20	12 25	145	113	35	11	18
Feb. 1	8 00	18 40	144	108	39	08	27
Feb. 2*	{ 2 10 } {23 05 }	17 05	147	114	36	13	21
Feb. 3	23 50	0 05	148	117	34	15	18
Feb. 22	23 25	7 35	152	107	49	20	33
Feb. 24*	9 14	19 15	149	71	85	15	68
Feb. 25	23 50	0 10	137	105	35	03	32
Feb. 27	6 40	16 10	141	100	45	03	36
Mar. 22	22 35	10 30	149	119	33	14	17
Mar. 26	2 40	19 40	148	107	45	11	32
Mar. 27	24 00	13 35	145	107	41	08	29
Apr. 3*	1 25	8 25	155	82	80	+ 13	62
Apr. 4	0 25	10 30	141	109	35	— 01	34
Apr. 19	20 30	18 30	145	110	38	+ 04	33
Apr. 24*	9 00	18 05	165	105	65	29	38
May 20	9 40	19 35	151	105	50	11	40
May 21	24 00	13 35	149	115	37	05	32
June 6	2 20	16 00	165	131	37	24	09
June 18	2 00	16 00	154	126	30	12	14
June 22	12 05	19 10	162	126	·0039	+ ·0021	— ·0015

† The great disturbance in November, 1882; as in the case of the declination, the curves traced by the bifilar magnet have been reproduced; see diagram No. 7.


8
7
6
3
2
1
h O
E 1h = 1.570 cm.
LOCAL MEAN TIME.
NOV. 17
NOV. 18
NOV. 19
NOV. 20
d
100
90
80
70
60
50
40
30
20
10
5
0
BIFILAR SCALE
1 div. = 0.000109 H = 0.0000298 dyne

-20, 1882

HORIZONTAL FORCE TRACES, NOV. 17–20, 1882

[NOT REDUCED TO STANDARD TEMPERATURE.]

MAGNETIC OBSERVATORY, LOS ANGELES, CAL.

Days of large disturbance in the horizontal component of the force at Los Angeles, Cal., October, 1882, to February, 1889—Continued.

Date.	Local mean time of extremes.		Extreme scale readings, 200*d.* +		Range of day in terms of H.	Magnitude of disturbance or difference from normal in terms of H.	
	Greatest force.	Least force.	Max.	Min.		Max.	Min.
1883.	*h. m.*	*h. m.*	*d.*	*d.*			
June 27	1 30	18 35	158	121	·0040	+ ·0016	— ·0020
June 30	6 15	16 00	147	116	34	04	25
July 8	8 30	6 35	166	134	35	33	04
July 10	2 10	6 00	162	115	51	26	26
July 11	13 55	17 40	150	113	40	13	25
July 15	7 00	15 40	147	115	35	11	23
July 18	1 20	18 45	162	121	45	26	16
July 29	16 00	19 55	152	109	47	18	29
July 30	4 30	18 35	142	106	39	03	33
Sept. 15*	19 30	22 35	167	51	126	39	85
Sept. 16*	14 40	19 45	134	77	062	03	60
Oct. 5	0 00	8 20	136	101	38	10	23
Oct. 16*	14 10	20 50	134	86	52	09	46
Nov. 1	{ 5 00 6 00 }	18 40	132	102	33	08	23
Nov. 2	14 00	19 00	123	84	42	01	42
Nov. 21	21 35	23 10	142	90	57	+ 22	36
Nov. 22*	5 00	0 35	119	76	47	— 06	54
1884.							
Feb. 23	9 00	16 50	133	93	44	+ 05	30
Feb. 29	9 50	21 50	132	81	56	08	46
Mar. 3	3 50	3 00	147	113	37	22	15
Mar. 28	2 00	21 45	130	92	41	03	35
Apr. 17	3 00	17 30	135	98	40	06	30
Apr. 24*	6 00	16 40	135	99	39	05	29
May 22	9 00	19 00	142	110	35	11	23
June 2	8 00	16 00	147	117	33	18	14
July 13	5 30	16 50	141	100	45	14	25
July 19	6 00	20 10	134	103	34	06	25
July 25	1 40	19 40	135	96	42	09	33
Aug. 21	3 00	15 10	131	100	34	04	26
Sept. 13	1 00	18 55	129	98	34	08	25
Sept. 17	4 35	18 55	129	72	62	08	54
Sept. 18	0 40	0 00	121	89	35	01	35
Oct. 1*	14 05	19 25	144	64	87	+ 32	56
Oct. 2	23 15	18 40	116	75	45	— 01	44
Nov. 1	6 25	22 45	127	95	35	+ 10	22
Nov. 2	8 05	18 20	119	66	58	02	54
Nov. 3*	5 30	0 05	124	77	51	08	41
Nov. 28*	4 15	0 00	124	96	30	08	21
Dec. 14	3 10	20 00	121	87	37	08	28
Dec. 19	15 00	23 05	125	95	·0033	+ ·0014	— ·0020

Days of large disturbance in the horizontal component of the force at Los Angeles, Cal., October, 1882, to February, 1889—Continued.

Date.	Local mean time of extremes.		Extreme scale readings, 200*d*. +		Range of day in terms of H.	Magnitude of disturbance or difference from normal in terms of H.	
	Greatest force.	Least force.	Max.	Min.		Max.	Min.
1885.	*h. m.*	*h. m.*	*d.*	*d.*			
Jan. 2	3 00 / 5 00	11 35	126	90	·0039	+·0013	—.0021
Jan. 22	7 30	12 15	122	74	52	06	38
Jan. 30	5 30	2 35	121	91	33	06	25
Feb. 10	3 10	12 10	136	97	42	26	13
Feb. 11	18 32	21 30	123	84	42	13	29
Feb. 28	7 00	18 37	120	88	35	08	25
Mar. 15*	0 08	19 00	123	65	63	13	51
Apr. 26	5 00	21 00	115	81	37	01	33
May 13*	1 00 / 2 00 / 3 00	15 35	116	67	54	03	47
May 25*	9 20	23 00	136	65	77	+ 27	50
May 26*	12 00	0 35	106	78	30	— 06	37
May 27*	21 20	22 55	112	76	39	+ 02	38
June 24‡	19 55	20 15	135	86	53	29	24
June 25‡	2 25	9 30	117	76	45	09	36
July 17	13 50	17 40	135	98	40	28	08
July 31	13 00	21 25	124	90	37	15	18
Aug. 1*	2 13	18 50	129	82	51	27	21
Aug. 7	2 05	16 50	118	84	37	15	17
Aug. 28	0 00	21 05	113	77	39	11	27
Sept. 4	23 45	15 50	115	70	49	18	29
Sept. 15*	5 35	21 30	112	69	47	13	29
Sept. 23	1 55	15 08	107	76	34	08	23
Nov. 11	2 45	13 20	114	77	40	20	16
Nov. 18*	4 45	12 45	109	64	49	13	30
Dec. 6	10 00	19 50	104	72	35	12	24
Dec. 7	8 15	16 05	101	65	39	05	32
1886.							
Jan. 9*	0 10	11 05	126	33	101	42	60
Jan. 28	9 15	23 25	105	76	032	13	14
Jan. 29	2 10	20 35	105	66	42	16	25
Feb. 10	9 00	20 20	96	65	34	00	29
Mar. 19	22 05	16 05	96	61	38	05	33
Mar. 28	5 00	17 48	99	69	33	04	25
Mar. 30*	1 53	12 35	133	8	131	44	88
Mar. 31	4 20	11 36	104	53	056	10	39
Apr. 13	1 30	22 30	98	69	32	06	24
Apr. 14*	3 35	22 50	99	57	46	08	37
Apr. 24	16 08	22 35	107	70	40	18	23
May 8*	4 35	18 25	105	41	70	11	53
May 9	0 06	1 06	98	57	45	05	41
May 17	23 10	20 00	106	70	39	13	23
June 5	4 46	17 36	106	74	·0035	+·0012	—·0017

‡This disturbance was one of considerable geographical extent.

Days of large disturbance in the horizontal component of the force at Los Angeles, Cal., October, 1882, to February, 1889—Continued.

Date.	Local mean time of extremes.		Extreme scale readings, 200*d.* +		Range of day in terms of H.	Magnitude of disturbance or difference from normal in terms of H.	
	Greatest force.	Least force.	Max.	Min.		Max.	Min.
1886.	*h. m.*	*h. m.*	*d.*	*d.*			
June 22	12 45	16 05	109	74	·0038	+ 00·15	— ·0018
June 25	10 30	17 40	100	69	34	05	24
June 29	24 00	20 16	106	55	56	14	39
June 30	0 05	16 53	112	70	46	21	22
July 27*	6 30	15 17	98	44	59	08	49
Aug. 12	0 40	18 25	100	65	39	11	24
Aug. 15*	23 40	19 55	97	69	30	09	20
Aug. 23	15 30	20 45	100	48	57	15	42
Sept. 9*	6 00	23 05	93	61	35	04	29
Sept. 10	23 45	16 05	104	63	45	17	26
Sept. 11	21 25	9 45	94	63	34	06	23
Oct. 6	6 55	17 15	95	50	49	12	36
Oct. 7	0 10	21 35	91	59	35	08	24
Oct. 8	5 30	8 30	89	54	38	04	27
Oct. 19	11 10	1 20	94	65	32	14	21
Nov. 2	7 02	16 30	92	56	39	14	23
Nov. 6	6 00	13 05	82	48	37	02	29
Nov. 30	3 15	11 45	91	59	35	13	17
1887.							
Jan. 22	9 00	21 30	92	55	40	16	20
Apr. 6	22 45	17 40	84	53	34	10	24
Apr. 14	13 10	22 07	87	57	33	14	20
May 12	11 10	17 05	94	55	42	22	21
May 23	13 58	18 55	92	55	40	18	20
July 7	2 45	18 55	94	54	44	16	24
Aug. 1	3 10	19 15	91	34	62	16	42
Aug. 2	23 45	21 05	85	56	32	11	18
Aug. 3	0 00	15 30	82	51	34	08	22
Aug. 28	{ 5 00 6 00 }	22 10	76	46	33	01	30
Aug. 29	2 25	14 05	85	54	34	10	20
Sept. 25	{ 5 00 6 00 }	19 20	79	12	73	08	64
Sept. 27	4 50	{ 16 10 18 50 }	76	45	34	03	28
Oct. 22	15 45	15 42	91	53	41	24	17
Oct. 26	6 05	15 10	80	49	34	11	21
Nov. 21	2 10	11 40	88	32	61	23	35
Dec. 21	7 00	19 55	69	35	37	03	30
1888.							
Jan. 7	8 35	23 50	75	44	34	13	17
Jan. 13	7 45	11 20	75	29	50	12	29
Jan. 23	5 55	16 50	78	35	47	16	28
Mar. 15	5 05	22 40	80	46	37	13	22
Apr. 2	15 45	21 10	75	44	·0034	+ .0008	— .0025

Days of large disturbance in the horizontal component of the force at Los Angeles, Cal., October, 1882, to February, 1889—Continued.

Date.	Local mean time of extremes.		Extreme scale readings, 200*d*. +		Range of day in terms of H.	Magnitude of disturbance or difference from normal in terms of H.	
	Greatest force.	Least force.	Max.	Min.		Max.	Min.
1888.	*h. m.*	*h. m.*	*d.*	*d.*			
Apr. 11	3 05	16 45	76	36	·0044	+ ·0007	— ·0035
May 20	3 17	21 08	87	17	76	21	54
June 3	0 20	18 30	77	42	38	10	26
June 22	6 15	18 00	79	48	34	10	18
Aug. 3	3 40	18 35	78	42	39	13	23
Aug. 15	23 05	21 00	79	48	34	16	17
Sept. 13	0 30	16 00	82	49	36	21	13
Oct. 19	2 00	15 30	69	35	37	10	26
Oct. 30	14 10	20 17	71	30	45	15	30
Dec. 23	{ 8 00 } { 9 00 }	20 18	63	30	·0036	+ ·0003	— ·0028

With our limit of counting any daily range equal to or exceeding 30 scale divisions (0.00327 H or 0·000892 of a dyne) a day of large disturbance, we find 170 disturbed days in 2 341 days, that is, 1 in 14, with an average daily disturbance range of 42 scale divisions, or 0·00458 H. This average disturbance range is to the ordinary daily range as 458 to 49, or as 9 to 1 nearly. Classified by magnitude for differences of 10 scale divisions, we have the following table:

Disturbance range.	Number of days.
d. *d.*	
30 to 40	105
40 50	34
50 60	14
60 70	5
70 80	5
80 90	2
above 90	5

In the great November storm of 1882, the maximum recorded range* was 144 divisions (·0157 H) on November 17, 3^h, as near as can be made out; this corresponds to a deflection from the normal for that time of 126 divisions, or ·0137 H.

The preponderance of the larger disturbances *decreasing* the horizontal force over those increasing the same is plainly brought out from the

*The trace passed to the edge of the paper and to some unknown distance beyond. See diagram No. 7.

Results of the differential measures of the horizontal intensity from observations recorded at Los Angeles, Cal.—Continued.

last two columns; the ratio of the disturbances decreasing (— of the table) to those increasing (+ of the table) the force is as 2·56 to 1.

THE LUNAR INFLUENCE ON THE HORIZONTAL COMPONENT OF THE MAGNETIC FORCE AT LOS ANGELES, CAL., 1883–1888.

The methods of investigation are in general the same as those followed in the discussion of the influence of the moon as exhibited by the variations in declination; hence it will suffice to refer to Part II of this paper for all matter of detail.

The data forming the basis of the investigation are the hourly records of the changes of the horizontal component, reduced to a uniform temperature of the magnet, as appended. Each ordinate was marked with the nearest lunar hour for future tabulation, and there were likewise marked the days of the several lunar phases, together with those of the moon's greatest and least declinations and of its apogee and perigee. As in the case of the declination effect, all values previously marked as disturbances were omitted from the tabulation.

Lunar-diurnal variation.—The effect of the moon on the earth's horizontal magnetic force is very minute and can only be made evident by eliminating, in the process of reduction, all larger variations due to other causes and by combining a large number (several thousands) of lunar values to a mean value. In the treatment adopted, the influences of diurnal and annual solar variations of the disturbances, of the sun spot inequality, and of the secular variation are all eliminated. Three years of differential record were selected, viz, the year 1883, the year 1885½–1886½, and the year 1888, yielding 7 579, 7 950, and 8 195 lunar differential ordinates, respectively; these numbers were found sufficient fairly to bring out the character and amount of the diurnal influence. The laborious nature of the investigations demands this restriction from 7 to 3 years.*

The following table contains for each hour-angle of the moon the mean value of all the differential ordinates at that hour-angle, *i. e.*, the difference between the tabular reading and its corresponding monthly mean reading of the bifilar record. A + sign indicates a northerly horizontal force greater than the normal, a — sign a southerly disturbing force.

---

*For the purpose in hand a total length of 410 meters (or nearly one-fourth of a statute mile) of photographic trace was employed, yielding altogether 23 724 ordinates, distributed over the 24 hour-angles of the moon. Since the average width of the trace is about one and a quarter scale division and, as will be seen, the total range of the lunar effect is but two-thirds of a division, the whole of the lunar-diurnal variation is confined to half the width of the trace.

Number and value of the hourly ordinates of the lunar-diurnal variation.

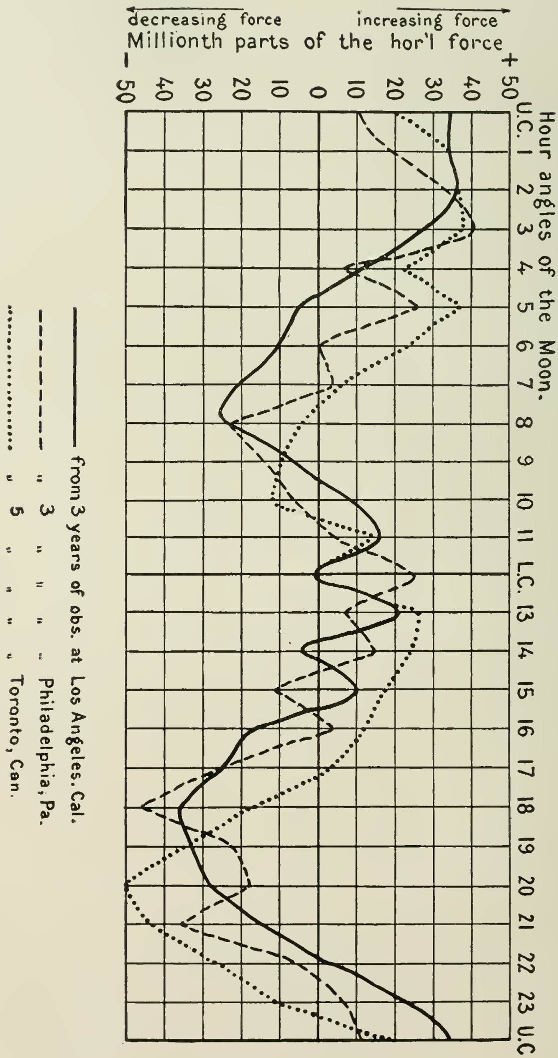
[One scale division equals 0·000109 part of the force, or in dynes 0·000109 × 0·2727 = 0·0000297 of a dyne. For the 23724 differential ordinates I am indebted to Mr. L. A. Bauer.]

Moon's hour-angle.	Number of measures of each.				Ordinates in scale divisions.				Los Angeles. 23 724 observations in 1883, 1885–1886, 1888—in parts of H.	Philadelphia. 22 045 observations in 1840-1845—in parts of H.*	Toronto. 34 303 observations in 1844–1848—in parts of H.†
	In 1883.	In 1885½–1886½.	In 1888.	Total.	1883.	1885½–1886½.	1888.	Mean.			
					d.	d.	d.	d.			
U. C.	320	335	341	996	+0·32	+0·46	+0·16	+0·31	+ 0·000034	+ 0·000011	+ 0·000019
1h	313	333	341	987	+0·21	+0·34	+0·39	+0·31	+ 34	+ 18	+ 34
2	309	336	341	986	+0·30	+0·45	+0·25	+0·33	+ 36	+ 33	+ 37
3	314	329	337	980	+0·27	+0·44	+0·09	+0·27	+ 29	+ 40	+ 38
4	318	337	339	994	+0·32	+0·22	—0·20	+0·11	+ 12	+ 07	+ 23
5	313	332	340	985	—0·08	+0·04	—0·10	—0·05	— 05	+ 26	+ 38
6	309	332	341	982	+0·03	—0·06	—0·25	—0·09	— 10	00	+ 23
7	315	330	340	985	—0·23	—0·14	—0·20	—0·19	— 21	+ 04	+ 06
8	320	334	343	997	—0·37	—0·06	—0·22	—0·22	— 24	— 22	— 05
9	315	337	345	997	—0·13	—0·07	+0·03	—0·06	— 07	— 15	— 10
10	319	335	344	998	0·00	+0·09	+0·11	+0·07	+ 08	— 07	— 12
11	315	327	344	986	—0.12	+0·41	+0·17	+0·15	+ 16	+ 04	+ 15
L. C.	322	340	344	1 006	—0·13	+0·02	+0·05	—0·02	— 02	+ 26	— 02
13h	318	332	341	991	+0·09	+0.18	+0·30	+0·19	+ 21	+ 07	+ 27
14	315	335	343	993	—0·17	—0·09	+0·11	—0·05	— 05	+ 15	+ 24
15	320	330	340	990	—0·08	+0·03	+0·31	+0·09	+ 10	— 11	+ 17
16	311	330	344	985	+0·06	—0·54	—0·01	—0·16	— 17	+ 04	+ 12
17	313	333	343	989	—0·12	—0·44	—0·12	—0·23	— 25	— 26	+ 03
18	313	324	346	983	—0·27	—0·49	—0·24	—0·33	— 36	— 47	— 19
19	314	324	339	977	—0·04	—0·60	—0·25	—0·30	— 33	— 22	— 35
20	317	321	342	980	—0·07	—0·45	—0·26	—0·26	— 28	— 18	— 50
21	320	328	336	984	—0·10	—0·17	—0·14	—0·14	— 15	— 36	— 44
22	320	327	340	987	+0·13	+0·06	—0·10	+0·03	+ 03	— 04	— 26
23	316	329	341	986	+0·36	+0·44	—0·17	+0·21	+ 0·000023	+ 0·000007	— 0·000010
Sums.	7 579	7 950	8 195	23 724	+0·18	+0·07	—0·29	0·00			

*U. S. C. S. Report for 1862, p. 207. One scale division equals 0·0000365 H.

† Toronto Observations, vol. III. One division of scale = 0·000087 in parts of H.

Lunar-diurnal Variation of the Horizontal Force.



Results of the differential measures of the horizontal intensity from observations recorded at Los Angeles, Cal.—Continued.

In the preceding table I have also given, for the purpose of comparison, the lunar-diurnal variation of the horizontal force at Philadelphia and at Toronto, the former from a three-year series by Dr. Bache, the latter from a five-year series of observations by Gen. Sabine. Not only is the general character of the lunar effect the same for the three stations, viz, a diurnal and a semidiurnal wave combined, but the amplitudes of the effect are almost identical when measured in parts of the horizontal force at each place. This close accord, especially when the extreme minuteness of the whole action is considered, is also brought out in the accompanying diagram No. 8, in which the figures of the last three columns of the preceding table have been plotted.

Expressed analytically the Los Angeles results are represented by

$$\begin{aligned} H_{☾} = -0{\cdot}000\,000\,1 &+ 0{\cdot}000\,014\,08 \sin (15n + 40^{\circ}{\cdot}1) \\ &+ 0{\cdot}000\,026\,18 \sin (30n + 63^{\circ}{\cdot}7) \\ &+ 0{\cdot}000\,001\,98 \sin (45n + 29^{\circ}{\cdot}5) \end{aligned}$$

where n = number of hours after upper culmination and $H_{☾}$ the corresponding horizontal force expressed in parts of H; for absolute measure in dynes multiply by 0·2727. This formula represents the observations as follows:

☾'s hour-angle.	Lunar-diurnal variation.		Diff. O—C	☾'s hour-angle.	Lunar-diurnal variation.		Diff. O—C
	Observed.	Computed.			Observed.	Computed.	
U. C.	+ 0·000034	+ 0·000034	0	L. C.	— 0·000002	+ 0·000013	—15
1^h	+ 34	+ 39	—5	13^h	+ 21	+ 13	+ 8
2	+ 36	+ 37	—1	14	— 05	+ 07	—12
3	+ 29	+ 26	+3	15	+ 10	— 03	+13
4	+ 12	+ 11	+1	16	— 17	— 15	— 2
5	— 05	— 04	—1	17	— 25	— 25	0
6	— 10	— 14	+4	18	— 36	— 33	— 3
7	— 21	— 19	—2	19	— 33	— 34	+ 1
8	— 24	— 16	—8	20	— 28	— 28	0
9	— 07	— 09	+2	21	— 15	— 15	0
10	+ 08	+ 01	+7	22	+ 03	+ 02	+ 1
11	+ 16	+ 09	+7	23	+ 23	+ 20	+ 3
							Σ +50 —49

We get the probable error of the representation of a single value by the simple formula,

$$r = 0{\cdot}845 \frac{[v]}{\sqrt{n(n-\nu)}} = \pm\, 4{\cdot}3 \text{ or } \pm\, 0{\cdot}000\,004\,3 \text{ part of H.}$$

At *Philadelphia* we have the expression for $\mathrm{H}_{☾}$ in parts of H (see p. 209, C. S. Rep. for 1862):

$$\mathrm{H}_{☾} = -0{\cdot}000\,000\,4 + 0{\cdot}000\,014\,60 \sin(15n + 13^{\circ}{\cdot}5) + 0{\cdot}000\,021\,90 \sin(30n + 38^{\circ}{\cdot}7) + 0{\cdot}000\,005\,64 \sin(45n + 244^{\circ}{\cdot}5)$$

and $r = \pm\,0{\cdot}000\,007\,8$ part of H.

At *Toronto* we have:

$$\mathrm{H}_{☾} = +0{\cdot}000\,004\,3 + 0{\cdot}000\,018\,80 \sin(15n - 6^{\circ}{\cdot}4) + 0{\cdot}000\,025\,95 \sin(30n + 15^{\circ}{\cdot}1) + 0{\cdot}000\,004\,68 \sin(45n + 97^{\circ}{\cdot}4)$$

and $r = \pm\,0{\cdot}000\,005\,7$.

To give an example of the lunar-diurnal effect at a station in the southern hemisphere I add here the result deduced by General Sabine from a 4½-year series of observations at St. Helena (Magnetical and Meteorological Observations at St. Helena, 1844–'49, Vol. II, London, 1860; Table XXXVII and p. CXLVII), slightly improved and changed to compare with above notation.

$$\mathrm{H}_{☾} = +0{\cdot}000\,002\,4 + 0{\cdot}000\,009\,21 \sin(15n + 265^{\circ}6) + 0{\cdot}000\,017\,67 \sin(30n + 130^{\circ}{\cdot}5) + 0{\cdot}000\,002\,13 \sin(45n + 284^{\circ}{\cdot}6)$$

In the following table I have put together for the North American stations the hour-angles of the moon for each of the four extremes of the diurnal action, as computed by means of the formula

$$\frac{d\,\mathrm{H}_{☾}}{d\,\theta} = b \cos(\theta + c) + 2\,b_{,} \cos(2\,\theta + c_{,}) + 3\,b_{,,} \cos(3\,\theta + c_{,,}) = 0$$

and introducing the numerical values from the given expressions for $\mathrm{H}_{☾}$.

	Principal maximum.	Secondary minimum.	Secondary maximum.	Principal minimum.
	h. m.	*h. m.*	*h. m.*	*h. m.*
At Los Angeles, Cal.	1 12	7 06	12 30	18 40
At Phi adelphia, Pa.	2 52	8 19	13 07	18 41
At Toronto, Can.	2 40	9 34	14 22	20 06
	Amount in parts of H.			
For Los Angeles, Cal.	+ ·000 0397	— ·000 0187	+ ·000 0136	— ·000 0342
For Philadelphia, Pa.	+ 032	— 016	+ 019	— 032
For Toronto, Can.	+ 0377	— 0040	+ 0229	— 0427

Results of the differential measures of the horizontal intensity from observations recorded at Los Angeles, Cal.—Continued.

Total lunar-diurnal range.

For Los Angeles, Cal.,	0·000 073 9 H.
For Philadelphia, Pa.,	64 0
For Toronto, Can.,	80 4

While the North American stations concur within an hour or two to assign the same position (hour-angle) of the moon for each of the above extremes of the horizontal force (respectively), it is otherwise at other stations; thus, J. A. Broun found from the Makerstown (Scotland) series of observations, 1843–'46—*

The greater maximum, $1\frac{1}{4}$ hours after lower culmination.
The greater minimum, 8 hours after upper culmination.
The smaller maximum, 2 hours after upper culmination.
The smaller minimum 3 hours before upper culmination.

Here the principal and subordinate extremes appear exchanged as compared with the American stations. At Prague (Bohemia), from a 10-year series, 1840–'49,† K. Kreil found the greater maximum about $4\frac{1}{2}$ hours after lower culmination, and the smaller maximum about $4\frac{1}{2}$ hours after upper culmination; also, the greater minimum about $10\frac{1}{2}$ hours after upper culmination, and the smaller one about $10\frac{1}{2}$ hours after lower culmination, showing the same feature in the diurnal inequality as at Makerstown.

How far the epochal quantities c $c_{,}$ $c_{,,}$ ...... remain constant at any one place remains to be seen.

Semiannual inequality in the lunar-diurnal variation.—If we combine the preceding results separately for the six months, October to March (inclusive), when the sun is in south declination and for the remaining six months, when the sun is in north declination, we get the following ordinates, in scale divisions, of the lunar-diurnal variation, where α = the moon's hour-angle, W the winter, and S the summer half year.

a	W.	S.	a	W.	S.
	d.	*d.*		*d.*	*d.*
U. C.	+·28	+·35	L. C.	—·09	+·05
1^h	+·31	+·33	13^h	+·18	+·21
2	+·37	+·30	14	+·03	—·11
3	+·29	+·23	15	+·09	+·08
4	+·10	+·12	16	—·31	—·03
5	+·05	—·15	17	—·46	—·03
6	—·01	—·18	18	—·63	—·03
7	—·10	—·28	19	—·47	—·11
8	—·12	—·31	20	—·22	—·30
9	+·04	—·16	21	—·11	—·17
10	+·14	+·01	22	+·04	+·01
11	+·21	+·10	23	+·19	+·22

* Trans. Roy. Soc. of Edinburgh, Vol. XIX, Part II, 1849, at Sir Thomas M. Brisbane's observatory.

† Denkschriften of the Imperial Academy of Sciences, Vienna, Vol. V, 1853. Einfluss des Mondes auf die horizontale Componente der magnetischen Erdkraft.

The average number of ordinates from which any tabular value is derived is 494. Thrown into curves, the tabular values for the six months with the sun in south declination, when contrasted with the values for the period with the sun in north declination, plainly show a greater minimum at $\alpha = 8^h$ (about) and a less minimum at $\alpha = 19^h$ (about) in summer than in winter. At Philadelphia a slightly greater range was noted for the summer months; at this place also the extremes of the double wave were found to occur earlier in winter than in summer. No such difference, however, can be detected at Los Angeles, though the principal minimum is 2 hours earlier in winter.

Variation of the lunar-diurnal force in the plane of the horizon.—The lunar-diurnal deflecting force acting in a horizontal plane may be represented in direction and intensity in the same manner as has been shown in the case of the solar-diurnal deflecting force.

In Part II of this discussion, the east and west component of the lunar disturbing force is given in seconds of arc for all hour-angles of the moon; multiplying these hourly values by $\frac{1}{206265}$ or by 0·000004848, we get their equivalent values in terms of the horizontal force H. The combination of the latter with the corresponding values of the north and south component gives the disturbing force throughout the lunar day, as shown by the accompanying diagram (illustration No. 9).

☾'s hour angle t.	E. and W. Component* in terms of H.	N. and S. Component† in terms of H.	☾'s hour angle t.	E. and W. Component* in terms of H.	N. and S. Component† in terms of H.
U. C.	— ·000034	+ ·000034	L. C.	— ·000030	— ·000002
1^h	— 012	+ 034	13^h	— 012	+ 021
2	+ 003	+ 036	14	— 003	— 005
3	+ 014	+ 029	15	+ 021	+ 010
4	+ 034	+ 012	16	+ 030	— 017
5	+ 042	— 005	17	+ 044	— 025
6	+ 042	— 010	18	+ 037	— 036
7	+ 025	— 021	19	+ 021	— 033
8	— 003	— 024	20	000	— 028
9	— 019	— 007	21	— 032	— 015
10	— 039	+ 008	22	— 039	+ 003
11	— 042	+ 016	23	— 034	+ 023

* Derived from 23 807 observations of the unifilar magnetometer; a + sign indicates a deflecting force to the east.

† Derived from 23 724 observations of the bifilar magnetometer; a + sign indicates a deflecting force to the north.

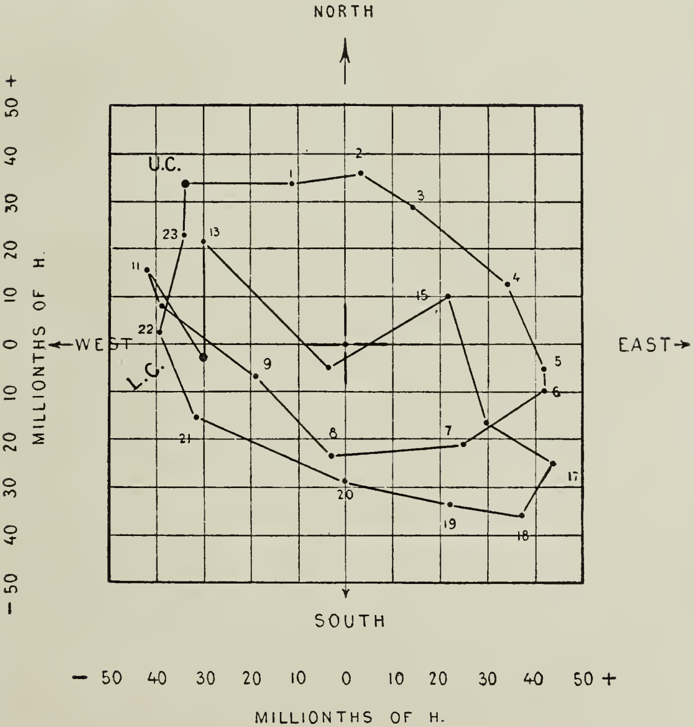
But for some slight irregularity in the curve about Lower Culmination the two convolutions are plainly brought out. In this respect the lunar field is unlike that of the solar field.

The linear scale (of force) of the lunar diagram is about 15 times greater than that of the solar ones, given on a preceding page. A line drawn from the center of the diagram to any hour mark of the curve

Los Angeles, Cal.

The lunar-diurnal deflecting force

from 3 years of obsn's.



Results of the differential measures of the horizontal intensity from observations recorded at Los Angeles, Cal.—Continued.

will indicate in direction and magnitude the deflecting force then acting.*

Inequality in the horizontal magnetic force depending on the variation of the lunar phases.

This investigation, as well as the two following ones, is based upon the 6-year hourly record between 1883 and 1888, inclusive, as appended to this paper, hence, comprises 74 lunations. The method followed is the same for the three investigations, viz, for any one case, *i. e.*, of phase, declination, or parallax, the daily means (resulting from 24 hourly readings, but omitting all larger disturbances) of the horizontal force on the day of occurrence, also on the 3 preceding and on the 3 following days were compared with a normal mean. This normal mean was obtained from the daily means of the *preceding* 14 days and of the following 14 days, counted from the day of the event. This normal mean was subtracted from the daily mean, as given by observation for the day of the event, and its six adjacent days. The differences are set down with their proper sign, a + sign indicating a greater, a − sign less force than the normal. The means of these differences were then tabulated† with the following results, expressed in scale divisions (one div. = 0·000 109 H):

Inequality in the horizontal force in relation with the lunar phases.

	37 lunations.		74 lunations.		37 lunations.		74 lunations.
	1883–'4–'5.	1886–'7–'8.			1883–'4–'5.	1886–'7–'8.	
3 days before ●.	−·1	+·5	+·2	3 days before ○.	+1·4	−·5	+·4
2 days before.	·0	·0	·0	2 days before.	+·6	−·8	−·1
1 day before.	−·1	+·3	+·1	1 day before.	−·1	−1·1	−·6
On day of new moon.	−·5	−·1	−·3	On day of full moon.	−1·3	−1·1	−1·2
1 day after.	−·1	+·5	+·2	1 day after.	−·1	−·7	−·4
2 days after.	+·1	+·2	+·1	2 days after.	−·5	−·3	−·4
3 days after.	+·3	+·6	+·4	3 days after.	−·4	+·2	−·1
3 days before ☽.	+·5	+1·1	+·8	3 days before ☾.	−·2	+·7	+·3
2 days before.	+1·0	+·1	+·6	2 days before.	+·3	+1·1	+·7
1 day before.	+1·1	−·4	+·4	1 day before.	+·2	+·6	+·4
On day of first quarter.	+1·1	+·2	+·7	On day of last quarter.	·0	+·8	+·4
1 day after.	+1·3	+·2	+·8	1 day after.	−·1	+·6	+·2
2 days after.	+2·1	−·3	+·9	2 days after.	−·1	+·4	+·2
3 days after.	+1·6	−1·4	+·1	3 days after.	+·1	+1·4	+·8

The figures of the last column, when shown graphically, plainly indicate an increase in the horizontal force about the times of first and last

**i. e.*, the force as expressed in parts of H, or, after multiplying with 0·2727, in dynes, with which a north magnet pole of unit strength would be urged in that direction.

†The work was performed by Mr. L. A. Bauer.

quarters and a decrease about the times of new and full moon. The range between these extremes may be set down as one scale division, or about 0.0001 part of the force. (See, also, accompanying diagram illustration No. 10.) The result from the observations at Philadelphia by Bache* (1840–'45), and the result found by Broun,† from the Makerstown observations (1843–'46), as well as the Prague observations (1843–'46), by Kreil, support this diminution of the force about new moon. Still, much uncertainty remains respecting the total action when different places are compared. This is readily explainable by the extreme smallness of the effect and its consequent entanglement with the numerous other variations, which can only be eliminated imperfectly.

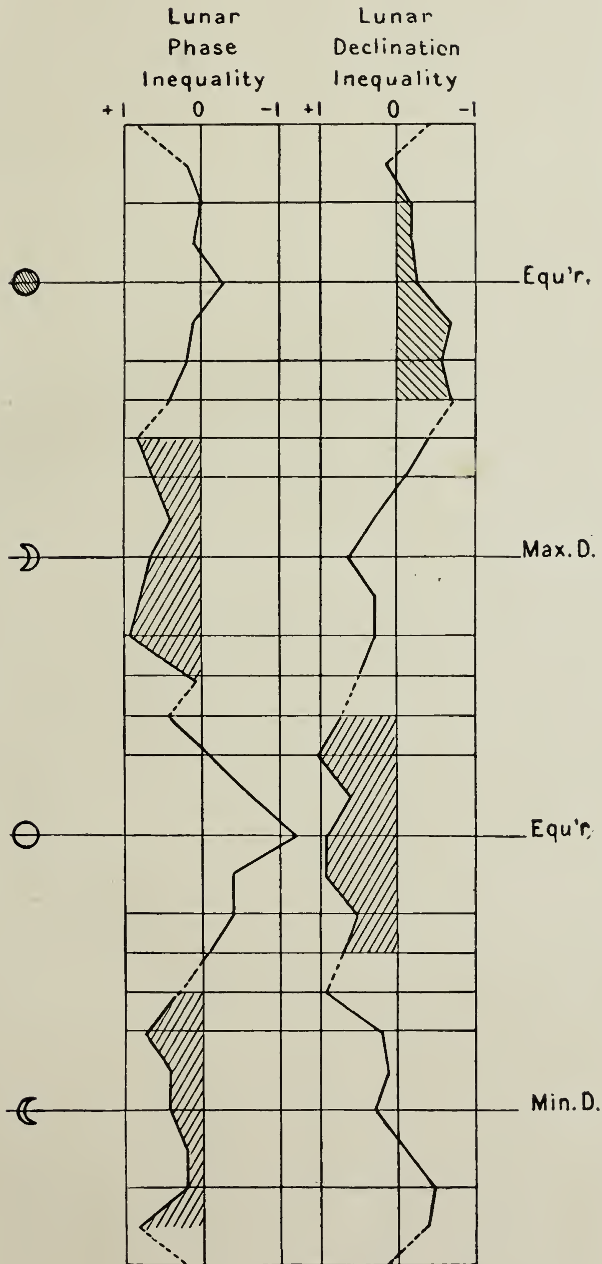
Inequality in the horizontal magnetic force depending on the variations of the moon's declination.—Following the same method as before we get for the effect depending on the moon's extreme declinations, and, when crossing the equator, the results as below. Each tabular value is the mean of 80 cases, covering the 6 years.

	3 years.		6 years.		3 years.		6 years.
	1883–'85.	1886–'88.	1883–'88.		1883–'85.	1886–'88.	1883–'88.
	d.	*d.*	*d.*		*d.*	*d.*	*d.*
3 days before.	+1·0	— ·9	+·1	3 days before.	+1·1	+ ·4	+ ·7
2 days before.	+ ·7	—1·2	—·2	2 days before.	+1·7	+ ·4	+1·0
1 day before.	+ ·7	—1·1	—·2	1 day before.	+ ·5	+ ·7	+ ·6
On day of zero declination.	+ ·6	—1·1	—·3	On day of zero declination.	+ ·9	+ ·9	+ ·9
1 day after.	— ·7	— ·8	—·7	1 day after.	+ ·9	+ ·9	+ ·9
2 days after.	— ·7	— ·5	—·6	2 days after.	+ ·6	+ ·4	+ ·5
3 days after.	—1·1	— ·4	—·7	3 days after.	+ ·8	+ ·6	+ ·7
3 days before.	—1·1	+ ·3	—·4	3 days before.	+ ·7	+1·0	+ ·9
2 days before.	— ·9	+ ·6	—·1	2 days before.	— ·4	+ ·8	+ ·2
1 day before.	— ·1	+ ·6	+·3	1 day before.	— ·9	+1·0	+ ·1
On day of extreme N. declination.	+ ·7	+ ·6	+·6	On day of extreme S. declination.	— ·3	+ ·9	+ ·3
1 day after.	+ ·5	+ ·2	+·3	1 day after.	— ·1	— ·1	— ·1
2 days after.	+ ·1	+ ·4	+·3	2 days after.	·0	—1·0	— ·5
3 days after.	+ ·6	+ ·4	+·5	3 days after.	+ ·6	—1·6	— ·4

These results indicate, if anything certain, a diminished horizontal component about the time the moon crosses the equator, with increasing + declination, and an increased force when crossing the equator, with increasing − declination. Apparently no decisive effect is seen about the times of the extreme declination of the moon. The figures presented in the table also seem to indicate a greater force at and shortly after the time of the moon's greatest north declination, and again shortly before and at the time of the moon's greatest south declination. They are further shown on the accompanying diagram.

*U. S. Coast Survey Report for 1862, pp. 210, 211.

†Trans. Roy. Soc. of Edinburgh, Vol. XIX, p. II.


Lunar Phase Inequality
Lunar Declination Inequality
+1 0 −1 +1 0 −1
Equ'r.
Max. D.
Equ'r.
Min. D.

Results of the differential measures of the horizontal intensity from observations recorded at Los Angeles, Cal.—Continued.

Inequality in the horizontal force depending on the variation of the moon's distance.—Applying the same method as before, but extending it to 4 days before and after the perigee and apogee, we get the following results, each the mean of 79 values and comprising the 6 years, 1883 to 1888:

	d.		*d.*
4 days before	+0·6	4 days before	+1·2
3 days before	+0·7	3 days before	—0·1
2 days before	+0·2	2 days before	—0·6
1 day before	—0·2	1 day before	—0·6
On day of perigee	+0·0	On day of apogee	—0·6
1 day after	+0·4	1 day after	—0·4
2 days after	+0·2	2 days after	—0·3
3 days after	+0·5	3 days after	—0·1
4 days after	+0·3	4 days after	—0·9

Hence, the force appears increased about perigee and diminished about apogee; the difference or range of this parallactic inequality is about + 0·3 + 0·2 or 0·5 scale division. This result is more in accordance with what might be expected than the opposite results found for Prague and Philadelphia, and both Sabine and Broun* have shown that the perigee effect exceeds that of the apogee, and the latter found it to be nearly as the inverse cube of the moon's distance from the earth.

THE PERIOD OF THE SOLAR ROTATION DEDUCED FROM VARIATIONS IN THE HORIZONTAL COMPONENT OF THE MAGNETIC FORCE.

In the preceding Part II an account has been given of the method followed in deducing the solar rotation period from the observed variations in the indications of the unifilar magnetometer, the same method depending on the inequalities of the daily variation has been employed with respect to the bifilar magnetometer. The hourly scale readings (corrected for changes of temperature of magnet) for the year 1883 were submitted to the process, but all of the larger disturbances (viz, those exceeding 9 scale divisions from the normal of the hour) were omitted. The normals being subtracted from the hourly readings of each month, a + sign of the respective difference indicate a horizontal force greater than the normal, a — sign the reverse. The average amounts of the positive and of the negative values for each day were separately made out and tabulated. The tabular values were next grouped for rotation periods of 24, 25, 26, 27, and 28 days, thus representing 14 periods. The means (of 14 values) for each rotation day and for increasing and decreasing force are given in the following table, to which two more groups, one of 29, the other of 30 days, were added in consequence of a suspected second periodicity connected, however, not with the sun but with the moon. The tabular numbers are expressed in scale divisions.

*Encycl. Brit. (9th edition), Vol. XVI, Art. Meteorology, p. 177.

Groups of mean diurnal range differences for various rotation periods.

Days of the period.	For increasing horizontal force.							For decreasing horizontal force.						
	I.	II.	III.	IV.	V.			I.	II.	III.	IV.	V.		
1	2·5	2·2	2·4	2·9	2·2	1·7	1·9	3·3	2·3	2·5	3·1	2·8	2·7	3·2
2	1·8	2·8	2·4	2·0	2·9	1·9	1·5	2·5	2·0	2·2	2·9	2·6	2·6	3·2
3	2·3	2·8	2·7	2·2	2·8	2·1	2·0	2·4	2·4	2·6	2·6	2·4	2·8	3·3
4	2·5	2·5	1·9	2·1	2·5	1·8	1·6	2·3	2·2	3·1	2·4	2·7	3·0	2·9
5	2·4	2·8	2·1	3·5	3·2	1·8	2·1	2·4	2·3	2·6	3·3	2·3	3·3	3·0
6	2·5	2·4	2·7	3·4	2·5	2·0	2·2	2·2	2·6	3·3	3·0	2·6	2·6	2·5
7	2·5	2·5	3·2	2·7	1·6	1·7	2·5	2·2	2·8	3·0	3·0	2·5	2·6	3·2
8	2·5	2·5	2·3	2·0	2·0	1·4	2·2	3·0	2·8	3·1	3·1	3·1	3·4	3·0
9	2·5	2·1	1·7	1·4	2·7	1·5	2·2	2·8	2·7	3·2	3·1	2·6	3·3	2·4
10	2·9	1·7	2·8	2·3	1·6	1·8	2·9	2·7	3·0	2·7	2·9	3·4	2·5	1·6
11	2·7	1·9	2·3	2·6	1·9	2·1	3·1	2·1	3·1	3·1	2·3	3·2	2·7	1·6
12	2·7	1·9	2·5	2·5	1·9	2·6	3·5	2·1	2·8	2·9	2·1	2·3	2·5	1·8
13	2·6	2·4	2·1	2·1	1·5	2·7	3·2	2·3	2·6	2·9	2·6	2·3	2·3	1·8
14	2·3	3·0	2·2	2·6	2·3	2·8	3·3	2·7	1·9	2·6	2·0	2·1	2·7	1·2
15	2·0	2·6	2·2	2·5	2·1	2·7	3·4	2·9	2·8	2·4	2·1	2·9	2·3	1·2
16	2·0	3·0	2·5	2·5	2·2	2·7	3·3	2·4	2·5	2·2	2·2	2·8	2·0	2·0
17	2·7	2·2	3·2	2·3	2·0	2·6	3·1	2·2	3·6	2·7	2·7	2·8	2·7	2·1
18	3·1	2·4	2·4	2·1	2·1	3·1	2·8	2·1	2·9	2·5	2·7	2·5	2·0	2·3
19	2·4	2·3	2·6	2·4	2·5	3·2	3·0	3·0	2·6	2·5	2·5	2·2	2·0	2·2
20	2·4	2·5	2·2	1·8	2·8	3·4	2·0	3·5	2·3	2·4	2·5	2·6	1·5	3·8
21	2·1	2·8	2·7	2·3	2·9	3·7	2·0	3·0	2·5	1·8	2·0	1·8	1·2	2·9
22	2·2	2·4	2·7	2·1	3·7	3·2	2·0	2·7	2·5	2·9	2·2	1·3	2·0	3·1
23	2·5	2·3	2·2	2·3	3·4	3·2	2·3	2·7	2·5	2·1	1·7	2·0	2·3	2·5
24	2·1	2·2	2·5	2·6	2·7	2·6	2·8	2·8	2·3	1·7	1·9	3·0	2·9	2·8
25		2·1	1·9	2·9	2·8	2·6	1·9		2·1	2·0	2·8	3·6	2·7	3·3
26			2·3	2·3	2·3	2·5	2·2			2·3	3·3	3·3	2·3	3·4
27				2·3	2·3	2·4	1·6				2·9	2·6	3·2	3·2
28					2·5	2·6	2·2					2·1	3·8	3·1
29						1·7	2·0						3·3	2·6
30							1·7							2·3
Mean	2·43	2·41	2·41	2·40	2·43	2·42	2·42	2·60	2·56	2·59	2·59	2·59	2·59	2·58

The larger means at the bottom of the table for horizontal force decreasing, as compared with force increasing, is due to the greater activity of the disturbances which decrease the force, as already investigated.

The numbers n for each of the periods p were next represented by an expression of the form:

$$h=a+b\sin\left(\frac{360}{p}n+c\right)$$

and they were likewise represented graphically; it was found that the numbers of that half of the table which referred to increasing force

Results of the differential measures of the horizontal intensity from observations recorded at Los Angeles, Cal.—Continued.

were too irregular to be of any value in the present inquiry; for the other half we have:

$$
\begin{array}{rl}
 & \quad\ \ \text{d.} \qquad \text{d.} \\
p = 24 & h = 2{\cdot}6 + 0{\cdot}235 \sin (n\,\theta + 117^\circ) \\
25 & \qquad\quad + 0{\cdot}347 \sin (n\,\theta - 90\ ) \\
26 & \qquad\quad + 0{\cdot}472 \sin (n\,\theta - 33\ ) \\
27 & \qquad\quad + 0{\cdot}342 \sin (n\,\theta + 9\ ) \\
28 & \qquad\quad + 0{\cdot}116 \sin (n\,\theta - 47\ )
\end{array}
$$

To determine that particular period P, for which the amplitude b becomes a maximum, we express the above amplitudes by the form

$$b = \alpha + \beta\,(p - 26) + \gamma\,(p - 26)^2$$

hence the observation equations:

$$
\begin{aligned}
0{\cdot}235 &= \alpha - 2\beta + 4\gamma \\
0{\cdot}347 &= \alpha - \beta + \gamma \\
0{\cdot}472 &= \alpha \\
0{\cdot}342 &= \alpha + \beta + \gamma \\
0{\cdot}116 &= \alpha + 2\beta + 4\gamma
\end{aligned}
$$

and the normal equations

$$
\begin{aligned}
1{\cdot}512 &= 5\,\alpha \qquad\qquad + 10\,\gamma \\
-0{\cdot}243 &= \qquad\quad 10\,\beta \\
2{\cdot}093 &= 10\,\alpha \qquad\quad + 34\,\gamma
\end{aligned}
\qquad \text{whence} \left\{
\begin{aligned}
\alpha &= +0{\cdot}4354 \\
\beta &= -0{\cdot}0243 \\
\gamma &= -0{\cdot}0665
\end{aligned}
\right.
$$

For the condition of the maximum we have:

$$\frac{db}{dp} = \beta + 2\gamma\,(p - 26) = o \ \text{ and } \ \text{P} = 26 - \frac{\beta}{2\gamma}$$
$$0 = -0{\cdot}0243 - 0{\cdot}1330\,(\text{P} - 26) \text{ and P} = 25{\cdot}82 \text{ days.}$$

The observed and computed amplitudes compare as follows:

Observed b.	Computed b.	O — C
·235	·218	+·017
·347	·393	—·046
·472	·435	+·037
·342	·345	—·003
·116	·121	—·005

From the reduction of the unifilar record the resulting value of the (magnetic) rotation period was found to be somewhat less than 26 days; the weight of the above result, however, from the bifilar record is very much stronger, and 25·8 days seems to be near an average value, deducible from the results by other investigators.

The greatest range due to solar rotation is twice 0·44 scale divisions, or 0·000048 in parts of H, as the result from 14 synodic solar rotations in the year 1883. According to Spoerer a rotation period of 25·8 days would correspond to the rotation deduced from the sun spots in heliographic latitudes of about 17°.

When the grouping of our differential range data was extended to 29 and 30 days, a second regularity made its appearance, both for the increasing and for the decreasing horizontal force, and which seemed to have its most prominent development for a period of about 29½ days. This points to a lunar origin (synodic revolution); the range considerably exceeds that just found for the solar rotation effect. The existence of a 29½-day period was noticed, long ago, by J. A. Broun, and referred by him to a lunar revolution.*

*See Trans. Roy. Soc., Edinb., Vol. xvi, 1846, and Phil. Trans. Roy. Soc., Vol. 166, 1876–'77.

DIFFERENTIAL MEASURES—

Hourly readings from the photographic traces of the bifilar

[Local mean time. 200 divisions plus tabular quantity, one division = 0·000109 in parts of H. All

OCTOBER, 1882.

[For the explanation of these tables see pp. 53, 54.]

Day.	1^h	2^h	3^h	4^h	5^h	6^h	7^h	8^h	9^h	10^h	11^h	Noon.
1	131	133	133	134	135	133	131	130	129	127	125	125
2	131	152*	134	138	123	109*	114*	119	112*	100*	99*	125
3	127	130	130	129	131	131	129	129	129	128	126	127
4	136	132	132	134	132	134	131	128	129	131	131	125
5	142*	141*	143*	147*	142*	145*	142*	141*	138*	141*	134*	125
6	122	118*	128	132	139	130	131	128	127	127	125	123
7	131	132	133	132	132	131	130	132	133	133	133	132
8	132	132	132	132	132	131	130	127	127	129	130	128
9	---	---	---	---	---	---	---	---	---	---	---	---
10	---	---	---	---	---	---	---	---	---	---	---	---
11	---	---	---	---	---	---	---	---	---	---	---	---
12	[133]	[133]	[133]	[134]	[134]	[133]	[132]	[130]	[128]	[128]	[126]	[127]
13	133	132	133	134	134	132	130	128	126	128	129	130
14	131	129	132	129	129	127	125	121	121	121	122	125
15	128	130	129	135	131	131	131	125	125	125	124	127
16	[128]	[128]	[128]	[128]	[127]	[126]	[124]	[122]	[119]	[118]	[116]	[117]
17	129	128	129	131	130	131	132	129	124	121	116	117
18	128	127	131	129	129	130	130	129	126	126	124	123
19	129	129	129	130	129	129	125	121	117	120	119	119
20	132	133	133	134	134	133	131	127	126	130	128	126
21	131	130	130	130	131	130	126	124	124	125	126	126
22	127	128	129	131	130	131	128	122	124	122	125	121
23	129	130	125	132	133	132	133	132	128	127	127	128
24	116*	121*	126	129	132	135	134	135	131	131	130	131
25	125	116*	129	129	130	129	129	127	125	125	124	129
26	130	132	132	132	132	132	129	130	125	124	125	125
27	128	131	133	133	135	135	134	130	128	127	127	129
28	131	132	132	131	134	138	131	129	126	128	120	114*
29	142*	129	130	125	129	130	128	126	125	123	120	126
30	135	132	130	129	129	131	129	131	124	117	118	124
31	131	133	131	131	132	131	130	129	129	[129]	[128]	[128]
Monthly mean	130·3	130·5	131·0	131·9	131·8	131·1	129·6	127·9	125·9	125·4	124·2	125·1
Normal	129·9	130·7	130·6	131·4	131·4	131·4	129·7	127·4	126·0	125·8	124·8	125·5

HORIZONTAL INTENSITY.

magnetometer of the Los Angeles Magnetic Observatory.

readings referred to standard temperature of magnet. Increasing numbers indicate increasing force.]

OCTOBER, 1882.

13^h	14^h	15^h	16^h	17^h	18^h	19^h	20^h	21^h	22^h	23^h	Mid-night.	Daily mean.	Daily range.
127	129	131	130	129	129	129	129	128	125	123	127	[129·3]	12^d
122	116	114*	[112*]	110*	118*	114*	123	132	125	125	125	[120·5]	77(?)
128	125	129	129	133	134	133	132	127	127	129	135	129·5	10
131	127	132	133	135	137*	137	137	136	136	135	142*	133·0	20
119	125	131	130	125	125	111*	93*	123	109*	116*	137	130·2	59
121	123	123	126	128	130	130	130	130	131	131	131	127·7	32
121	129	129	128	130	132	133	133	132	133	132	132	131·2	14
130	132	131	[128]	[128]	[130]	[130]	[129]	[129]	[132]	[130]	[132]	[130·1]	[9]
---	---	---	---	---	---	---	---	---	---	---	---	---	--
---	---	---	---	---	---	---	---	---	---	---	---	---	--
---	---	---	---	---	---	---	---	---	---	---	---	---	--
[127]	[127]	[129]	[128]	128	128	128	128	131	131	131	136	[130·1]	[10]
130	131	130	130	[130]	131	131	132	131	131	131	131	[130·8]	12
128	129	125	121	118*	122	131	124	125	129	130	136	126·3	18
127	128	129	129	[129]	[129]	[130]	[128]	[127]	[129]	[127]	[128]	[128·4]	11
[116]	[116]	[117*]	[116*]	115*	121	118*	118*	120	134	129	137	[122·4]	22(?)
121	121	124	[123]	123	124	127	128	129	129	129	131	[126·1]	23
122	122	123	124	127	129	129	128	128	129	128	128	127·0	11
122	124	127	129	129	129	130	130	131	131	131	131	126·7	15
127	118	129	129	130	131	132	131	131	131	130	130	129·8	16
127	128	128	128	128	128	130	128	126	129	128	126	127·8	8
116	117	120	113*	120	122	123	120	123	130	130	127	124·1	19
128	128	129	128	129	129	130	131	117*	150*	119*	120*	128·9	41
134*	136*	137*	137*	133	134	135	137	123	124	120	115*	129·8	31
130	124	127	126	127	125	124	126	129	133	137	132	127·4	17
122	124	125	126	126	127	128	129	128	129	130	123	127·7	16
126	127	129	129	123	119	130	121	112*	131	123	128	127·9	35
115*	116	119	113*	114*	121	122	118*	127	122	125	126	124·3	28
124	122	127	125	124	127	131	131	128	129	129	130	127·5	24
127	127	128	130	131	129	129	129	129	129	130	130	128·2	21
[128]	[127]	[129]	128	128	128	129	129	130	128	128	130	[129·3]	6
124·9	124·9	126·8	126·0	126·1	127·4	128·0	126·9	127·2	129·5	128·1	129·9	127·93	
124·9	124·5	127·3	127·7	128·0	127·4	129·6	128·9	128·2	129·5	128·9	130·4		

DIFFERENTIAL MEASURES—

Hourly readings from the photographic traces of the bifilar

[Local mean time. 200 divisions plus tabular quantity, one division = 0·000109 in parts of H. All

NOVEMBER, 1882.

[For the explanation of these tables see pp. 53, 54.]

Day.	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	Noon.
1	128	130	132	131	131	129	130	127	126	125	123	124
2	132	131	132	130	128	129	130	126	124	124	125	125
3	128	131	133	130	131	128	127	124	121	117	117	121
4	130	130	126	130	130	130	129	126	125	126	126	127
5	132	132	133	132	133	132	132	129	125	122	121	122
6	128	129	129	131	132	134	133	128	124	118	123	124
7	136	131	130	129	130	132	132	123	124	119	124	122
8	127	128	131	130	129	131	130	127	127	127	126	126
9	126	127	130	131	134	131	127	126	124	118	119	122
10	131	131	131	132	132	132	130	130	125	126	123	124
11	134	134	133	134	134	133	131	129	126	124	124	128
12	109*	133	122	123	133	130	126	120	124	114	108*	109*
13	109*	113*	121	113*	134	115*	105*	117	99*	104*	98*	108*
14	120	120	121	121	122	123	113*	114*	112*	110*	104*	113
15	109*	115*	122	122	129	128	131	127	115*	115	114	116
16	131	126	125	130	126	128	129	127	124	125	126	123
17	127	126	148*	91*	96*	93*	93*	90*	80*	86*	89*	89*
18	93*	94	115*	87*	93*	98*	100*	96*	99*	92*	69*	95*
19	112*	111	117*	117*	117*	101*	104*	105*	108*	115	118	113
20	123	81	66*	88*	80*	103*	83*	89*	86*	78*	81*	83*
21	108*	108	109*	111*	110*	112*	112*	90*	73*	79*	78*	81*
22	112*	113	114*	114*	115*	115*	114*	112*	111*	109*	108*	109*
23	117*	118	121	118*	118*	117*	122	117	117	111*	110*	109*
24	120	121	122	122	121	123	123	123	125	122	119	121
25	123	123	123	125	125	125	122	126	125	98*	107*	121
26	120	120	120	121	121	121	125	115*	125	125	121	118
27	125	123	126	125	124	124	125	122	122	119	118	117
28	130	129	127	126	129	128	130	128	130	122	119	121
29	[131]	[131]	[133]	[131]	[132]	[131]	[130]	[127]	[125]	122	119	121
30	125	131	134	133	134	135	135	133	132	130	126	123
Monthly mean	122·5	122·3	124·2	121·9	123·4	123·0	121·8	119·1	116·8	114·1	112·8	115·2
Normal	127·6	128·0	127·4	128·1	129·3	129·0	128·6	125·5	124·8	121·7	121·6	121·5

HORIZONTAL INTENSITY—Continued.

magnetometer of the Los Angeles Magnetic Observatory.

readings referred to standard temperature of magnet. Increasing numbers indicate increasing force.]

NOVEMBER, 1882.

13^h	14^h	15^h	16^h	17^h	18^h	19^h	20^h	21^h	22^h	23^h	Mid-night.	Daily mean.	Daily range.
125	123	128	129	130	131	135	135	133	132	132	135	129·3	14^d
125	125	128	127	139*	135	143*	132	134	128	128	128	129·5	24
125	127	126	127	128	127	130	130	130	129	129	129	126·9	17
129	128	129	130	131	132	133	133	133	134	131	131	129·5	10
116	124	126	128	125	124	125	129	129	128	130	128	127·4	17
126	127	126	129	126	129	130	129	128	129	132	131	128·1	17
120	121	124	126	129	129	129	128	129	131	129	130	127·4	17
123	124	126	128	127	127	127	126	128	129	128	129	127·5	9
126	123	117	119	128	129	129	129	129	129	130	130	126·4	17
126	126	126	131	132	132	132	133	133	132	132	133	129·8	11
126	127	129	144*	144*	136	133	131	133	128	147*	116*	131·6	33
106*	105*	98*	98*	94*	88*	107*	104*	84*	89*	85*	125	109·8	61
103*	101*	98*	113*	118*	115*	115*	108*	111*	116*	122	127	111·8	47
118	125	127	130	133	130	130	134	122	122	116*	130	121·2	38
117	122	126	124	129	129	131	128	128	127	125	125	123.2	25
124	121	126	123	130	138	128	126	127	127	125	126	126·7	26
96*	98*	80*	57*	33*	18*	41*	6*	85*	42*	61*	88*	79·7	144
91*	76*	78*	95*	98*	104*	113*	110*	103*	108*	107*	109*	96·8	56
115	117	118	116*	98*	48*	70*	63*	53*	63*	55*	52*	96·1	90
95*	91*	80*	82*	94*	98*	105*	101*	105*	106*	107*	108*	92·2	89
86*	81*	92*	99*	111*	114*	113*	112*	111*	115*	117*	116*	101·6	47
110*	112*	114*	117*	117*	116*	120	117*	117*	117*	122	117*	114·3	16
115	118	120	120	116*	118*	119	119*	119*	123	118	118*	117·4	15
121	121	124	122	113*	115*	120	120*	118*	118*	119	119*	120·5	13
120	121	117	98*	110*	113*	114*	120*	117*	118*	122	120*	118·0	32
117	119	121	121	120*	120*	120	132	125	125	124	136	122·2	21
119	123	125	128	129	128	127	129	129	127	125	126	124·4	13
122	126	129	130	130	127	127	126	126	128	[129]	[131]	[127·1]	13(?)
128	130	133	134	134	133	133	133	131	129	127	133	[129·6]	15(?)
122	121	129	133	134	132	128	126	127	125	130	130	129·5	15
116·4	116·8	117·3	118·6	119·3	117·2	120·2	118·4	119·2	118·5	119·5	121·9	119·18	
122·0	123·4	125·2	127·0	129·7	130·4	127·9	130·1	129·2	128·1	126·8	129·6		

DIFFERENTIAL MEASURES—

Hourly readings from the photographic traces of the bifilar

[Local mean time. 200 divisions plus tabular quantity, one division = 0·000109 in parts of H. All

DECEMBER, 1882.

[For the explanation of these tables see pp. 53, 54.]

Day.	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	Noon.
1	129	130	129	131	131	130	130	131	130	125	122	122
2	128	128	128	129	129	130	130	131	134	131	130	128
3	129	129	130	130	131	132	133	132	130	130	126	125
4	130	125	128	129	131	129	135	135	125	132	128	128
5	129	130	130	130	131	133	134	133	130	123	122	123
6	132	132	131	132	132	133	134	134	133	132	130	127
7	132	133	133	133	133	134	135	136	133	132	129	129
8	133	133	133	134	134	134	134	134	133	[133]	[133]	135*
9	133	132	132	134	135	134	134	136	133	134	136	133
10	133	134	135	133	135	136	135	136	134	133	133	130
11	136	137	134	133	134	135	137	136	131	130	130	128
12	129	129	136	132	131	132	132	130	128	128	127	128
13	134	134	134	135	135	133	134	133	131	127	123	123
14	135	136	136	137	137	137	138	137	135	130	127	129
15	136	137	142*	141	142*	140	141	140	139	137	131	128
16	121	116*	120*	117*	120*	121*	122*	128	130	132	126	118
17	128	130	130	132	134	133	134	132	131	126	124	123
18	130	130	130	132	132	132	132	132	132	130	127	125
19	122	129	128	128	128	129	130	132	133	130	124	121
20	127	132	130	135	134	141	147*	148*	143*	128	115*	116*
21	125	114*	125	120*	117*	123*	124*	122*	126	122	108*	109*
22	129	127	130	126	128	128	127	126	131	127	124	120
23	130	128	129	132	129	131	133	130	128	123	116*	117
24	131	133	132	130	131	128	131	135	134	127	122	123
25	131	132	132	133	134	131	131	132	135	133	128	125
26	132	133	133	133	133	134	137	138	139	136	132	132
27	131	133	132	133	134	134	135	135	136	133	127	126
28	127	129	129	131	[132]	[133]	[134]	[135]	[135]	132	130	128
29	126	128	129	135	132	136	136	138	143*	139	136	128
30	131	132	133	133	135	136	137	138	139	128	127	130
31	129	131	133	133	135	132	135	136	136	132	126	125
Monthly mean	129·9	130·2	131·2	131·5	131·9	132·4	133·6	133·9	133·2	130·2	126·4	125·2
Normal	129·9	131·2	131·2	132·4	132·5	133·1	133·9	133·8	132·6	130·2	127·9	125·8

HORIZONTAL INTENSITY—Continued.

magnetometer of the Los Angeles Magnetic Observatory.

readings referred to standard temperature of magnet. Increasing numbers indicate increasing force.]

DECEMBER, 1882.

13^{h}	14^{h}	15^{h}	16^{h}	17^{h}	18^{h}	19^{h}	20^{h}	21^{h}	22^{h}	23^{h}	Mid-night.	Daily mean.	Daily range.
123	126	127	118*	122*	126	126	128	128	125	126	127	126·7	14^{d}
126	127	128	128	128	125	126	127	127	129	128	133	128·7	10
127	128	130	131	130	131	131	128	132	130	129	135	130·0	11
119	122	123	122	129	130	129	130	129	129	129	129	128·1	19
122	125	127	130	130	132	133	132	132	132	132	133	129·5	13
128	130	130	131	131	131	131	133	134	134	133	132	131·7	8
126	130	132	134	134	134	133	133	133	133	132	132	132·4	10
135*	135	134	134	136	136	136	136	132	128	128	132	[133·5]	10
129	123	126	130	133	131	130	130	131	132	133	133	132·0	10
131	132	135	137	137	136	132	129	133	132	140*	135	134·0	13
128	130	131	124	130	128	129	127	127	125	129	129	130·7	21
129	130	132	136	136	134	134	133	133	132	133	134	131·6	10
127	131	134	136	136	136	134	134	133	134	134	134	132·5	13
132	135	138	138	138	138	137	137	136	135	136	135	135·4	11
127	134	137	153*	138	126	126	124	129	127	125	130	134·6	37
116*	128	133	135	133	133	136	130	131	132	130	129	126·5	25
125	127	130	133	134	133	128	127	126	129	130	130	129·5	13
124	121	126	120*	133	131	127	116*	116*	141*	115*	116*	127·1	35
121	123	126	127	130	129	130	128	129	130	127	132	127·8	18
120	116*	104*	102*	95*	104*	112*	102*	103*	105*	131	119*	121·2	61
116*	118*	122	123	120*	126	124	124	134	126	124	128	121·7	27
118	121	124	123	128	126	125	123	127	129	125	131	126·0	14
118	125	126	131	132	131	132	130	130	129	131	133	128·1	17
124	129	132	133	132	131	131	130	130	131	130	134	130·2	14
126	128	132	132	134	133	132	133	131	132	131	132	131·4	11
132	134	136	142*	142*	137	134	133	129	131	132	130	134·3	14
131	135	133	133	131	123	123	126	127	125	122	124	130·1	15
129	130	131	132	132	128	128	124	123	130	128	129	[130·0]	11(?)
129	132	130	123	129	132	133	130	129	130	130	132	131·9	21
128	132	131	125	130	132	131	131	128	129	129	130	131·5	16
124	125	129	131	132	132	132	130	133	134	132	130	131·1	13
125·5	127·8	129·3	129·9	130·8	130·2	129·8	128·3	128·9	129·7	129·5	130·4	130·00	
125·8	128·6	130·1	130·5	132·4	131·0	130·4	129·7	130·2	130·1	129·6	131·3		

DIFFERENTIAL MEASURES—

Hourly readings from the photographic traces of the bifilar

[Local mean time. 200 divisions plus tabular quantity, one division = 0·000109 in parts of H. All

JANUARY, 1883.

[For the explanation of these tables see pp. 53, 54.]

Day.	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	Noon.
1	133	133	134	134	133	137	137	134	133	128	121	118*
2	132	133	133	134	134	135	136	136	133	126	124	127
3	132	130	135	136	136	136	136	138	137	134	129	129
4	136	136	136	137	139	138	139	140	137	131	130	130
5	132	134	135	136	137	139	140	139	138	135	136	136
6	133	137	134	138	136	141	144	142	137	132	135	131
7	131	136	140	137	136	136	136	137	135	131	128	130
8	128	132	137	137	132	137	139	135	133	130	126	132
9	136	133	134	134	135	135	133	132	132	130	125	128
10	136	136	136	136	137	137	135	134	131	129	130	132
11	133	133	132	132	132	132	131	130	129	126	126	129
12	137	138	136	137	138	138	137	135	131	127	130	133
13	138	138	138	138	139	139	138	136	136	131	131	130
14	134	136	136	137	138	138	138	138	135	130	126	124
15	138	138	138	138	139	139	138	136	131	127	128	134
16	135	135	135	137	136	138	138	138	136	131	126	128
17	138	138	137	138	139	138	141	133	137	134	129	127
18	142	135	133	134	134	135	138	138	135	132	121	127
19	138	138	138	138	139	139	139	138	133	131	128	128
20	134	132	133	134	136	136	136	134	135	135	128	127
21	134	134	133	134	140	137	137	140	141	138	131	131
22	139	138	139	143	141	140	141	139	136	134	132	133
23	140	139	137	138	139	140	140	139	138	133	129	129
24	[138]	[138]	[139]	[139]	[139]	[140]	[140]	[139]	[138]	134	125	132
25	137	137	137	138	138	135	137	135	138	131	116*	118*
26	130	127	137	131	133	137	138	136	138	127	119	121
27	135	134	134	135	136	136	137	136	135	132	128	128
28	134	134	134	135	135	135	136	138	139	138	134	133
29	136	135	136	136	136	136	135	135	135	131	126	122
30	137	136	137	138	138	138	138	138	137	134	130	128
31	132	132	136	138	136	138	138	138	139	135	130	126
Monthly mean	135·1	135·0	135·8	136·4	136·6	137·3	137·6	136·6	135·4	131·5	127·6	128.4
Normal	135·1	135·0	135·8	136·4	136·6	137·3	137·6	136·6	135·4	131·5	128·0	129·1

HORIZONTAL INTENSITY—Continued.

magnetometer of the Los Angeles Magnetic Observatory.

readings referred to standard temperature of magnet. Increasing numbers indicate increasng force.]

JANUARY, 1883.

13^h	14^h	15^h	16^h	17^h	18^h	19^h	20^h	21^h	22^h	23^h	Mid-night.	Daily mean.	Daily range.
122	127	130	132	130	130	131	131	132	132	132	132	130·7	19^d
127	128	130	131	133	134	134	135	134	134	134	135	132·2	12
130	131	133	136	137	137	138	136	136	136	136	136	134·6	10
132	134	134	134	134	133	130	131	131	133	132	131	134·1	11
131	135	139	139	133	133	135	133	134	134	130	132	135·2	14
130	135	137	136	136	134	136	135	132	131	126	129	134·9	18
132	131	133	132	130	133	131	130	127	132	140	129	133·0	17
131	132	132	131	131	133	133	132	133	130	132	131	132·5	14
129	134	134	136	136	137	137	137	136	135	136	135	133·7	10
134	135	139	136	133	131	129	130	131	133	134	133	133·6	11
132	135	136	138	138	138	138	138	138	138	138	139	133·8	13
134	135	136	135	136	138	138	138	138	138	138	138	135·8	12
131	133	135	137	137	138	139	139	138	137	139	135	136·3	10
130	132	136	139	139	140	140	139	139	138	138	139	135·8	16
136	141	137	136	135	133	132	134	134	134	134	136	135·2	16
134	139	141	143	137	137	138	138	136	134	140	139	136·2	17
130	135	137	133	135	136	136	134	132	127	133	132	134·5	15
131	132	136	137	136	134	136	137	137	136	136	136	134·5	21
130	134	137	138	138	138	138	138	136	136	137	135	135·9	11
129	130	130	129	130	132	132	133	130	131	131	132	132·0	12
133	134	134	136	138	138	138	139	138	138	137	138	136·3	12
130	132	135	138	139	140	139	138	139	138	139	138	137·5	13
133	138	139	139	139	138	137	136	136	137	[138]	[138]	[137·0]	11
137	137	138	137	135	133	137	136	136	137	136	133	[136·4]	[15]
119*	127	133	135	134	130	131	126	122*	122*	132	128	130·7	28
123	133	130	130	132	134	133	127	129	131	133	133	130·9	32
130	131	133	131	128	131	131	131	128	128	128	132	132·0	12
134	135	134	132	134	136	133	131	134	134	134	134	134·6	9
122	134	132	131	135	136	137	135	134	135	134	136	133·3	16
128	129	129	132	133	135	136	134	134	134	133	136	134·3	11
127	133	133	135	133	135	135	136	134	135	136	136	134·4	15
130·0	133·3	134·6	135·0	134·6	135·0	135·1	134·4	133·8	133·8	134·7	134·4	134·25	
130·4	133·3	134·6	135·0	134·6	135·0	135·1	134·4	134·2	134·2	134·7	134·4		

DIFFERENTIAL MEASURES—

Hourly readings from the photographic traces of the bifilar

[Local mean time. 200 divisions plus tabular quantity, one division = 0·000109 in parts of H. All

FEBRUARY, 1883.

[For the explanation of these tables see pp. 53, 54.]

Day.	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	Noon.
1	136	138	140	138	140	142	142	144	142	128	134	134
2	125*	143	134	130	132	129	137	128	129	116*	124	125
3	127	126*	128	130	131	130	135	134	128	123*	120*	124
4	131	131	132	131	135	134	134	134	135	122*	118*	119
5	135	134	135	133	133	134	134	134	129	133	132	132
6	132	132	133	134	136	135	136	131	122*	126	134	134
7	134	134	134	135	133	135	136	135	133	131	128	128
8	134	134	135	135	135	137	135	132	130	132	131	132
9	136	136	136	136	136	136	137	135	133	129	127	130
0	135	135	135	136	136	139	142	141	138	133	131	132
	139	137	137	138	139	141	139	139	134	128	126	129
12	138	138	138	138	140	140	136	133	131	128	125	127
13	140	141	141	141	142	141	141	140	137	132	130	134
14	134	137	139	140	141	144	142	145	140	135	135	134
15	135	135	136	137	137	139	139	140	140	135	134	135
16	138	138	138	139	140	140	138	143	147*	145*	141	136
17	135	137	138	138	140	139	141	140	138	138	137	133
18	135	137	137	135	139	140	139	139	139	140	139	136
19	136	136	137	138	137	137	138	140	139	140	138	134
20	158*	136	137	139	140	143	141	138	138	136	136	135
21	139	136	138	137	138	138	139	140	141	141	140	140
22	132	138	137	138	135	139	138	137	130	133	129	127
23	132	124*	130	133	132	132	134	135	131	130	128	124
24	135	135	140	137	137	144	141	136	146*	143*	139	132
25	111*	112*	123*	124*	129	126*	127*	126*	128	131	131	131
26	129	130	130	132	132	132	132	132	130	127	129	129
27	139	132	134	135	136	134	140	133	137	119*	125	124
28	134	135	129	139	134	133	134	132	142	140	128	130
Monthly mean	134·4	134·2	135·0	135·6	136·2	136·9	137·4	136·3	135·3	131·9	131·0	130·7
Normal	134·8	135·8	135·5	136·0	136·2	137·3	137·8	136·7	134·9	133·0	132·0	131·1

HORIZONTAL INTENSITY—Continued.

magnetometer of the Los Angeles Magnetic Observatory.

readings referred to standard temperature of magnet. Increasing numbers indicate increasing force.]

FEBRUARY, 1883.

13^h	14^h	15^h	16^h	17^h	18^h	19^h	20^h	21^h	22^h	23^h	Mid-night.	Daily mean.	Daily range.
118*	122*	128	128	128	128	116*	120*	123*	120*	124*	122*	130·6	36^d
119*	121*	117*	121*	115*	129	130	130	129	126	143*	125	127·4	33
125	127	127	129	132	133	128	128	132	130	131	144*	129·2	31
121*	125	128	128	128	130	126	130	130	129	134	132	129·0	26
131	128	129	134	132	126	131	128	128	130	130	131	131·5	12
125	132	132	131	132	133	133	132	132	132	133	134	131·9	14
130	131	132	132	133	134	134	133	134	134	134	134	132·9	9
135	135	135	135	134	133	133	134	135	133	134	136	133·9	8
134	135	137	137	136	134	135	133	133	132	133	135	134·2	10
134	136	135	138	139	138	137	137	136	136	135	139	136·4	12
134	136	139	139	138	140	139	138	137	138	138	138	136·7	15
132	136	136	138	138	139	139	139	139	139	139	140	136·1	16
134	136	137	138	140	139	139	138	141	141	140	135	138·2	13
136	137	132	132	133	135	129	129	133	133	133	135	136·0	22
139	141	141	135	133	135	133	132	133	134	135	136	136·2	10
138	139	138	137	136	137	138	138	137	136	135	137	138·7	12
131	129	124	124	128	133	135	135	135	136	135	136	134·8	19
131	134	140	139	138	137	138	133	132	133	135	136	136·7	16
132	135	137	137	135	136	138	138	139	139	139	136	137·1	10
134	135	134	135	135	136	137	137	137	137	135	136	137·7	27
137	130	128	122*	127	127	130	129	126	128	131	130	133·8	19
128	123*	115*	113*	115*	112*	126	129	129	127	130	132	128·8	45
118*	126	129	127	132	133	134	132	132	133	137	135	130·5	19
119*	113*	129	128	105*	98*	84*	101*	107*	108*	115*	108*	124·2	78
130	132	130	129	131	129	128	132	125	126	126	136	127·3	32
130	133	132	129	131	130	131	132	132	131	130	129	130·6	7
119*	119*	126	102*	121*	123*	126	125	125	128	135	123*	127·5	41
128	120*	128	128	124	127	126	121*	123*	131	127	131	130·2	22
129·4	130·2	131·2	130·2	130·3	130·9	130·5	130·8	131·2	131·4	133·2	132·9	132·80	
132·2	133·1	132·4	132·8	133·0	133·2	132·8	132·8	132·8	132·8	133·9	134·3		

DIFFERENTIAL MEASURES--

Hourly readings from the photographic traces of the bifilar

[Local mean time. 200 divisions plus tabular quantity, one division = 0·000109 in parts of H. All

MARCH, 1883.

[For the explanation of these tables see pp. 53, 54.]

Day.	1^h	2^h	3^h	4^h	5^h	6^h	7^h	8^h	9^h	10^h	11^h	Noon.
1	131	129	134	131	136	136	133	136	136	131	122*	126
2	135	127*	130	134	133	136	131	130	135	132	133	131
3	136	133	133	133	134	134	133	135	134	136	[135]	[134]
4	135	137	136	136	136	136	134	131	133	132	128	129
5	133	135	136	139	137	136	136	137	137	138	138	137
6	138	138	138	138	139	139	139	141	143	144	148*	144*
7	132	139	136	135	135	138	134	134	136	146*	143	138
8	130	132	133	135	138	135	139	138	135	137	139	133
9	135	134	135	135	133	136	136	132	130	131	133	137
10	136	136	137	137	137	136	136	135	135	135	133	132
11	140	140	140	139	141	141	139	139	140	140	138	136
12	142	143	143	144	144	142	141	142	143	141	136	133
13	128	128*	137	136	139	134	131	131	133	131	129	129
14	134	133	137	142	141	138	138	138	138	138	140	137
15	139	137	138	138	138	139	141	141	141	138	133	132
16	138	139	139	141	141	141	140	137	135	136	136	136
17	140	142	141	142	142	142	141	140	140	138	136	135
18	141	141	143	142	143	142	141	140	142	143	141	138
19	142	142	142	142	142	143	143	143	139	142	140	138
20	141	145	145	145	145	144	143	140	136	139	141	141
21	137	140	138	140	143	142	141	141	139	138	133	128
22	131	126*	128*	133	136	139	132	133	131	127	123*	128
23	137	138	138	140	140	141	136	138	132	131	130	129
24	139	140	140	140	139	139	138	136	132	131	130	130
25	140	141	141	141	141	140	138	139	138	138	135	132
26	141	141	143	136	139	137	139	138	135	133	134	136
27	127	136	133	130	129	135	134	129	118*	114*	121*	123*
28	135	133	135	136	136	135	131	130	128	121*	127	124*
29	134	139	134	141	133	134	136	130	128	134	133	131
30	139	140	140	140	139	140	139	136	136	137	135	136
31	140	143	143	142	142	141	139	135	135	132	133	135
Monthly mean	136·3	137·0	137·6	138·2	138·4	138·4	137·2	136·3	135·3	135·0	134·0	133·2
Normal	136·3	138·1	137·9	138·2	138·4	138·4	137·2	136·3	135·8	135·8	134·9	133·5

HORIZONTAL INTENSITY—Continued.

magnetometer of the Los Angeles Magnetic Observatory.

readings referred to standard temperature of magnet. Increasing numbers indicate increasing force.]

MARCH, 1883.

13^h	14^h	15^h	16^h	17^h	18^h	19^h	20^h	21^h	22^h	23^h	Mid-night.	Daily mean.	Daily range.
130	132	130	130	132	126	134	124*	122*	129	131	136	130·7	20d
123*	127	128	128	127	123*	121*	122*	123*	130	127	126*	129·2	21
[134]	[135]	[136]	[137]	[137]	135	135	135	133	136	135	131	[134·5]	[11]
128	129	130	132	132	130	132	128	129	129	135	135	132·2	10
136	135	135	134	137	138	138	137	137	138	138	138	136·7	6
144*	149*	148*	144	131	138	136	134	134	132	131	140	139·6	19
141	143	140	139	137	134	132	128	126*	124*	127	128*	135·2	26
128	127	135	137	133	128	127	125*	136	131	135	135	133·4	20
137	137	136	134	134	133	133	134	135	135	136	135	134·4	9
131	130	135	138	138	138	139	138	138	135	138	139	135·9	9
138	139	141	142	142	140	140	140	142	141	141	140	140·0	7
135	130	139	138	138	137	138	138	134	133	121*	119*	137·2	25
131	133	134	133	133	132	133	132	134	134	132	130	132·4	26
136	134	135	135	136	135	135	133	135	134	136	140	136·6	10
133	135	137	137	138	137	138	139	139	138	137	137	137·5	10
137	138	140	140	140	140	139	141	141	140	140	142	139·0	7
133	134	137	137	134	139	140	140	137	140	140	141	138·8	10
137	139	139	139	139	140	142	142	142	141	141	142	140·8	6
140	143	144	144	144	144	144	143	144	144	144	145	142·6	8
142	143	146*	147*	147*	148*	149*	150*	143	142	138	135	143·1	17
128	132	124*	128	132	125*	121*	122*	122*	125*	127	140	132·8	26
129	131	136	134	137	131	131	134	134	142	143	135	132·7	30
132	133	134	139	138	132	133	133	132	136	142	140	135·6	14
132	134	134	135	136	135	133	134	137	140	137	139	135·8	12
136	139	141	142	141	140	138	136	136	139	136	144	138·8	14
130	136	124*	124*	119*	122*	114*	109*	124*	132	133	134	131·4	39
111*	111*	115*	127*	129	128	132	128	128	129	131	145	126·8	38
128	132	131	136	136	124*	134	129	138	127*	127	132	131·0	25
130	135	136	137	132	130	132	138	139	138	139	139	134·7	18
136	139	141	143	142	140	137	140	141	141	142	142	139·2	9
136	136	137	139	140	138	139	138	139	140	142	140	138·5	12
133·0	134·5	135·4	136·4	135·8	134·2	134·5	133·7	134·6	135·3	135·5	136·9	135·70	
133·7	134·8	136·2	136·8	136·0	135·3	135·7	135·7	136·8	136·4	136·0	138·2		

DIFFERENTIAL MEASURES—

Hourly readings from the photographic traces of the bifilar

[Local mean time. 200 divisions plus tabular quantity, one division = 0·000109 in parts of H. All

APRIL, 1883.

[For the explanation of these tables see pp. 53, 54.]

Day.	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	Noon.
1	140	143	141	142	141	141	143	141	140	139	138	136
2	146	141	142	143	143	143	142	140	135	138	138	138
3	147	146	144	151	129*	123*	124*	109*	106*	110*	117*	119*
4	131*	129*	129*	130*	130*	129*	125*	124*	122*	117*	122*	124*
5	136	144	137	138	140	135	136	132	129	131	127*	125*
6	138	139	138	138	138	137	135	131	126*	124*	125*	130
7	139	140	140	140	142	142	141	137	132	128	131	133
8	138	139	138	139	139	139	139	138	139	137	137	138
9	146	145	148	147	145	145	145	143	137	133	134	137
10	144	144	146	147	148	148	148	147	142	140	141	142
11	140	143	142	142	143	143	142	139	139	140	142	140
12	144	142	142	143	145	142	140	138	138	138	140	140
13	150	146	145	144	146	146	144	141	141	138	135	140
14	142	143	143	144	145	144	143	141	142	140	137	136
15	144	146	145	145	146	148	147	146	147*	147*	144	143
16	149	146	146	147	147	148	147	146	142	144	141	140
17	146	145	142	145	146	146	144	138	134	134	136	139
18	144	145	140	142	139	142	140	142	139	136	134	134
19	146	138	137	141	137	138	136	138	135	132	131	132
20	144	137	136	136	138	135	134	128*	129	130	132	136
21	139	139	138	140	140	142	142	140	135	132	131	133
22	142	142	142	139	140	142	141	138	135	134	133	134
23	143	143	144	145	145	146	146	144	143	141	139	136
24	150	150	152*	152*	155*	156*	161*	164*	165*	151*	149*	145
25	131*	132*	132*	129*	130*	130*	135	131	130	126*	125*	128*
26	142	138	137	137	138	136	135	136	128*	134	138	137
27	140	140	143	138	136	139	138	138	136	133	132	135
28	139	139	139	140	140	141	141	142	142	144	146*	145
29	143	141	142	140	141	143	144	145	144	143	142	141
30	143	143	144	143	146	147	145	140	141	143	139	138
Monthly mean	142·2	141·6	141·1	141·6	141·3	141·2	140·8	138·6	136·4	135·2	135·2	135·8
Normal	143·0	142·4	141·5	142·1	142·1	142·2	141·2	139·7	137·5	136·7	136·7	137·6

HORIZONTAL INTENSITY—Continued.

magnetometer of the Los Angeles Magnetic Observatory.

readings referred to standard temperature of magnet. Increasing numbers indicate increasing force.]

APRIL, 1883.

13^h	14^h	15^h	16^h	17^h	18^h	19^h	20^h	21^h	22^h	23^h	Mid-night.	Daily mean.	Daily range.
134	133	135	139	138	141	140	140	142	143	140	139	139.5	11^d
136	138	138	137	136	137	141	143	144	141	140	144	140.2	11
115*	97*	99*	112*	117*	119*	122*	128*	122*	124*	123*	130*	122.2	73
130	130	130*	135	133	133	135	135	134	138	139	140	130.2	32
128*	128*	131*	135	135	137	132	132*	137	135	145	139	134.3	20
133	137	140	141	138	138	138	139	139	139	138	139	135.8	18
135	138	140	139	139	139	140	142	143	139	139	137	138.1	17
138	140	140	138	141	140	142	142	143	144	145	145	139.9	8
139	136	139	139	140	139	138	138	140	143	143	144	141.0	16
144	142	143	143	140	142	141	141	142	139	140	138	143.1	10
142	143	143	145	145	145	142	142	142	143	147	142	142.3	8
141	140	143	145	146	147	146	147	146	146	147	144	142.9	10
143	142	141	142	139	140	142	142	142	141	142	143	142.3	15
138	139	142	145	145	144	143	144	145	144	144	144	142.4	9
142	143	143	140	140	141	144	144	143	144	146	146	144.3	9
142	146	149	149	148	145	146	146	145	141	144	144	145.3	9
142	144	147	147	146	145	146	146	145	147	147	147	143.5	14
130	135	140	142	136	135	138	131*	134	133	126*	135	137.2	27
125*	125*	127*	122*	118*	115*	111*	121*	137	130*	135	132	130.8	35
133	137	137	137	137	134	134	136	137	138	138	138	135.4	17
137	139	142	142	141	142	141	141	141	142	142	142	139.3	12
137	139	141	143	142	140	141	143	143	143	143	143	140.0	10
140	143	146	147	147	146	147	147	147	148	150	151*	144.8	16
134	113*	124*	109*	109*	107*	115*	118*	123*	127*	123*	129*	136.7	60
133	134	124*	138	136	131	129*	137	140	145	136	135	132.4	24
135	134	134	131*	131	134	132	139	135	140	144	138	136.0	17
136	135	141	141	139	138	138	141	141	143	142	141	138.5	12
143	143	144	142	139	140	140	140	141	141	141	143	141.5	7
140	140	139	139	140	142	143	143	142	142	143	142	141.8	7
140	138	139	142	141	141	142	141	140	132*	139	140	141.1	16
136.2	135.7	137.4	138.2	137.4	137.2	137.6	139.0	139.8	139.8	140.4	140.5	138.75	
137.7	138.8	141.1	141.2	139.9	139.9	140.5	141.6	141.1	141.6	142.2	140.9		

DIFFERENTIAL MEASURES—

Hourly readings from the photographic traces of the bifilar

[Local mean time. 200 divisions plus tabular quantity, one division = 0·000109 in parts of H. All

MAY, 1883.

[For the explanation of these tables see pp. 53, 54.]

Day.	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	Noon.
1	140	137	138	140	137	139	137	135	136	137	140	142
2	139	139	140	141	142	144	140	142	143	142	139	138
3	143	147	144	143	144	145	145	143	141	141	141	145
4	142	144	144	142	142	142	142	140	142	144	145	146
5	143	143	144	144	144	145	146	141	137	138	139	141
6	143	143	144	144	149	148	147	144	142	144	144	145
7	144	145	145	143	145	145	143	139	138	140	144	145
8	147	148	148	145	146	147	145	139	139	141	142	142
9	144	144	144	143	144	145	142	144	139	141	141	140
10	145	146	146	146	145	146	145	143	142	145	142	142
11	146	147	146	146	146	147	144	143	144	144	147	146
12	146	146	147	146	147	147	145	146	149	148	148	149
13	149	149	148	147	149	147	144	138	142	147	149	150
14	143	143	142	143	145	144	145	142	142	143	143	143
15	147	146	144	144	145	147	145	141	143	145	145	145
16	143	145	145	148	151	148	144	138	145	144	150	151
17	148	151	149	151	151	153	151	140	140	143	146	151
18	145	145	145	147	146	145	141	140	142	148	149	147
19	146	147	145	145	144	148	147	146	146	142	139	141
20	145	146	144	144	145	146	146	145	146	150	145	144
21	134*	126*	137	136	136	135*	144	136	134	133	128*	128*
22	141	137	136	138	136	138	137	136	133	134	138	140
23	139	138	139	139	139	140	141	136	135	135	136	139
24	144	142	142	140	141	143	145	143	139	137	136	141
25	141	142	141	140	142	141	140	137	136	137	136	138
26	143	142	142	143	143	142	141	135	137	139	137	139
27	144	144	144	144	144	145	145	144	142	142	139	139
28	144	143	142	142	144	143	144	141	140	142	143	141
29	144	139	140	140	141	140	137	142	140	141	141	143
30	145	146	145	142	144	144	143	141	142	143	146	149
31	142	143	143	143	143	141	139	137	136	139	142	146
Monthly mean	143·5	143·3	143·3	143·2	143·9	144·2	143·2	140·5	140·4	141·6	141·9	143·1
Normal	143·8	143·9	143·3	143·2	143·9	144·5	143·2	140·5	140·4	141·6	142·4	143·6

HORIZONTAL INTENSITY—Continued.

magnetometer of the Los Angeles Magnetic Observatory.

readings referred to standard temperature of magnet. Increasing numbers indicate increasing force.]

MAY, 1883.

13h	14h	15h	16h	17h	18h	19h	20h	21h	22h	23h	Mid-night.	Daily mean.	Daily range.
139	138	139	135	135	130*	129*	130*	138	139	140	149	137·5	20d
139	140	140	141	140	142	142	142	141	142	142	143	141·0	6
147	147	146	144	141	141	142	143	139	140	142	141	143·1	9
146	146	143	142	139	142	143	144	142	143	143	142	142·9	7
144	144	143	141	141	138	138	141	141	148	140	143	142·0	11
144	142	142	143	143	142	143	141	141	144	146	144	143·8	9
147	145	145	145	143	143	143	143	145	148	147	147	144·0	10
141	144	139	139	142	143	144	142	143	142	141	148	143·2	14
142	143	143	144	142	143	143	141	143	144	144	145	142·8	7
145	148	149	147	146	142	142	144	145	145	146	146	144·9	8
145	146	147	147	144	144	145	145	144	144	145	146	145·3	6
147	146	144	145	145	145	145	146	146	146	148	149	146·5	4
149	147	145	146	145	141	141	143	138	140	142	141	144·9	10
143	143	144	144	146	146	145	145	144	144	144	144	144·0	5
147	148	149	150	148	147	150	147	150	149	148	144	146·4	10
150	148	146	145	142	145	146	145	146	146	148	148	146·1	15
150	149	147	141	135	137	143	142	142	145	142	145	145·5	20
144	141	141	140	142	143	146	145	146	141	139	146	143·9	10
143	143	144	142	142	141	140	141	141	142	143	143	143·4	11
145	147	142	139	130*	123*	110*	110*	111*	129*	134	137	137·6	46
122*	124*	135	134	130*	123*	130*	131*	135	136	133*	149	132·9	34
134*	138	132*	132*	129*	133	136	143	131*	137	142	141	136·3	22
143	143	145	139	136	137	139	140	141	141	141	141	139·2	9
143	147	144	137	136	135	138	140	140	139	143	143	140·7	14
142	143	141	142	144	144	143	140	140	142	142	148	140·9	13
142	138	140	138	139	137	138	142	144	140	142	141	140·2	10
137	139	139	138	137	138	140	140	144	142	141	142	141·4	15
141	138	137	136	139	138	140	140	142	139	139	140	140·8	10
143	145	142	142	143	142	143	143	143	142	143	145	141·8	9
147	143	141	142	143	142	141	142	140	138	132*	137	142·4	17
148	149	145	143	141	140	140	142	141	145	144	143	142·3	15
143·2	143·3	142·5	141·4	140·3	139·6	140·3	140·7	140·9	142·0	142·1	143·9	142·18	
144·2	143·9	142·9	141·7	141·4	141·1	142·1	142·6	142·2	142·4	142·8	143·9		

DIFFERENTIAL MEASURES—

Hourly readings from the photographic traces of the bifilar

[Local mean time. 200 divisions plus tabular quantity, one division = 0·000109 in parts of H. All

JUNE, 1883.

[For the explanation of these tables see pp. 53, 54.]

Day.	1^h	2^h	3^h	4^h	5^h	6^h	7^h	8^h	9^h	10^h	11^h	Noon.
1	145	146	144	146	144	146	143	139	139	140	148	147
2	144	140	141	141	143	144	134	139	125*	135	143	141
3	135	141	136	136	138	138	136	137	141	143	144	146
4	140	142	143	143	142	143	140	140	142	144	144	146
5	144	144	144	144	145	145	143	141	146	149	149	150
6	149	161*	148	149	141	141	142	143	146	147	143	141
7	141	141	141	141	141	142	141	139	140	142	143	140
8	144	144	143	144	143	144	146	142	142	[144]	145	142
9	142	141	140	143	142	143	142	142	146	148	149	150
10	145	145	145	145	145	143	140	141	144	148	150	153*
11	142	142	143	143	145	146	144	145	151*	155*	156*	155*
12	150	149	149	148	147	149	150	150*	151*	154*	158*	156*
13	144	143	144	144	147	148	148	147	151*	150	149	148
14	146	146	147	146	147	147	146	140	139	141	143	143
15	148	148	147	147	148	149	145	141	144	146	146	148
16	146	145	144	149	147	147	144	139	138	141	146	150
17	143	148	144	152	145	145	142	138	139	140	149	154*
18	144	154*	140	140	140	138	135	132	128*	128*	135	138
19	139	141	143	141	141	139	138	135	134	137	147	143
20	142	143	141	143	143	145	142	140	137	138	139	138
21	142	142	141	142	142	144	141	138	137	136	133*	133*
22	154*	152	151	146	149	151	151*	145	142	145	148	158*
23	138	144	144	142	144	138	138	133	134	138	135	132*
24	140	141	140	140	141	139	136	133	132	132*	135	135
25	142	141	142	142	143	142	142	140	134	136	134*	139
26	148	141	140	141	143	143	139	137	141	145	142	142
27	143	151	145	146	145	139	138	133	133	137	132*	126*
28	136	136	136	137	135	134*	130*	126*	128*	135	133*	133*
29	141	139	139	140	141	140	137	139	142	146	144	143
30	138	139	139	138	141	142	141	140	124*	123*	134*	140
Monthly mean	143·2	144·3	142·8	143·3	143·3	143·1	141·1	139·1	139·0	141·4	143·2	143·7
Normal	142·8	143·5	142·8	143·3	143·3	143·4	141·2	139·2	139·6	142·0	144·2	143·5

HORIZONTAL INTENSITY—Continued.

magnetometer of the Los Angeles Magnetic Observatory.

readings referred to standard temperature of magnet. Increasing numbers indicate increasing force.]

JUNE, 1883.

13^h	14^h	15^h	16^h	17^h	18^h	19^h	20^h	21^h	22^h	23^h	Mid-night.	Daily mean.	Daily range.
148	147	142	139	138	136	133	137	140	148	141	142	142·4	17^d
140	134	135	131	130	132	132	140	140	140	140	136	137·5	20
142	139	146	136	134	136	138	138	140	141	142	142	139·4	13
145	144	140	137	138	139	141	142	142	143	144	144	142·0	10
146	143	143	143	143	146	147	146	145	149	151	148	145·6	10
140	142	138	131	135	134	136	143	140	140	141	145	142·3	34
141	142	138	138	140	141	139	139	140	141	142	143	140·7	6
138	141	144	141	139	143	145	142	139	141	144	146	142·8	9
144	144	140	140	138	138	139	142	143	145	145	145	143·0	12
149	147	139	141	141	143	143	142	142	143	144	143	144·2	15
151	150	151*	145	143	142	143	145	146	146	147	148	146·8	15
151	147	145	143	143	143	144	144	144	144	139	142	147·5	16
147	146	146	142	141	145	144	144	147	147	148	155*	146·5	14
142	144	143	142	141	142	143	143	145	146	146	147	143·9	10
150	149	147	146	143	144	147	149	147	147	146	145	146·5	10
153*	157*	152*	148	144	140	139	135	136	138	138	138	143·9	26
145	146	149	137	137	139	138	140	140	148	147	141	143·6	19
136	139	139	126*	138	137	132	138	136	142	147	140	137·6	28
142	140	142	139	135	139	140	140	142	141	140	143	140·0	14
136	142	142	139	136	137	136	138	138	145	140	140	140·0	10
139	142	144	142	142	141	142	143	143	145	145	148	141·1	16
150	150	146	138	127*	137	129*	136	130*	140	144	139	144·1	36
138	139	136	138	134	131	134	137	138	143	138	140	137·8	15
140	137	138	139	137	136	140	141	141	141	140	141	138·1	10
143	140	140	137	134	138	140	143	142	142	142	146	140·2	13
142	142	141	141	141	140	142	146	146	137	139	137	141·5	13
130*	137	138	136	129*	130	123*	132	138	133*	135	135	136·0	37
133*	135	136	137	137	136	137	137	138	137	141	139	135·1	15
139	136	136	138	138	137	138	138	140	144	138	140	139·7	14
139	135	130*	116*	119*	126*	119*	126*	126*	128*	137	134	132·2	31
142·6	142·5	141·5	138·2	137·2	138·3	138·1	140·2	140·5	142·2	142·4	142·4	141·40	
143·1	142·0	141·2	139·4	138·5	138·7	139·7	140·7	141·4	143·0	142·4	142·0		

DIFFERENTIAL MEASURES—

Hourly readings from the photographic traces of the bifilar

[Local mean time. 200 divisions plus tabular quantity, one division + 0·000109 in parts of H. All

JULY, 1883.

[For the explanation of these tables see pp. 53, 54.]

Day.	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	Noon.
1	133	135	135	135	137	137	132	133	129	126*	125*	128*
2	130	131	130	131	130*	131	129	126*	125*	126*	132	138
3	137	140	136	136	137	137	137	135	135	135	134	135
4	136	137	136	137	136	135	132	129	128	134	135	135
5	141	136	137	137	140	138	136	135	131	128	138	138
6	141	144	144	143	143	146	145	139	135	133	137	141
7	142	145	147	147	148	151*	152*	144	139	139	138	145
8	151*	138	140	141	140	142	136	152*	149*	148*	150*	141
9	144	141	142	143	145	141	140	139	140	145	147*	143
10	140	142	135	138	142	147	141	139	136	139	142	143
11	138	139	138	138	138	139	140	141	139	141	141	144
12	136	131	133	133	135	134	132	129	130	134	134	131
13	136	136	137	134	137	140	139	140	140	137	131	129
14	143	141	147	147	148	140	140	145	142	142	137	131
15	137	137	136	136	141	144	147*	138	133	140	142	144
16	139	141	138	138	136	136	135	132	134	132	129	131
17	137	136	134	135	135	138	138	134	131	132	131	130
18	156*	152*	140	143	143	146	143	140	140	132	127	127*
19	138	136	135	138	137	137	136	131	130	131	129	132
20	136	137	137	136	136	136	132	132	132	130	133	140
21	139	138	139	139	138	139	135	130	129	131	136	139
22	141	141	142	141	142	142	142	139	135	137	139	141
23	146	145	143	141	142	143	143	144	144	144	142	139
24	140	141	142	140	142	141	140	140	139	142	146*	147*
25	138	140	140	139	139	138	137	133	134	137	138	141
26	143	142	142	144	141	142	142	141	139	139	139	140
27	134	136	136	135	136	136	136	132	137	141	146*	143
28	139	139	138	140	140	140	136	136	138	141	140	137
29	138	138	139	139	139	141	139	136	138	139	139	139
30	130	132	135	138	130*	130*	130	135	126*	127*	122*	120*
31	114*	117*	119*	122*	124*	124*	128*	123*	123*	121*	129	129
Monthly mean	138·5	138·2	137·8	138·2	138·6	139·1	137·7	136·2	134·8	135·6	136·4	136·8
Normal	138·3	138·4	138·4	138·7	139·7	139·5	137·3	136·5	135·4	136·7	135·7	137·7

HORIZONTAL INTENSITY—Continued.

magnetometer of the Los Angeles Magnetic Observatory.

readings referred to standard temperature of magnet. Increasing numbers indicate increasing force.]

JULY, 1883.

13h	14h	15h	16h	17h	18h	19h	20h	21h	22h	23h	Mid-night.	Daily mean.	Daily range.
129*	128*	126*	129	121*	116*	119*	117*	121*	122*	129	132	128·1	23d
139	143	138	135	133	131	137	135	137	137	138	139	133·4	20
136	137	137	136	132	134	130	134	137	138	135	136	135·7	11
135	133	129	133	134	137	136	137	139	136	137	136	134·7	10
137	137	139	133	130	128	130	134	135	135	136	140	135·4	15
144	142	140	140	140	140	138	143	145	145	150*	145	141·7	20
143	142	141	143	144	143	144	146*	144	142	135	130	143·1	25
144	144	140	136	140	146*	140	141	142	141	139	140	142·5	32
142	143	141	140	139	144	132	130	131	141	137	133	140·1	18
142	136	137	138	134	115*	128	132	136	137	135	139	137·2	47
147	147*	143	136	122*	119*	131	124*	121*	131	130	136	136·0	37
132	131	130	131	132	134	136	138	135	138	139	137	133·5	12
133	132	135	137	136	138	138	138	138	138	137	144	136·7	16
128*	127*	126*	131	133	134	135	135	135	135	137	139	137·4	24
140	136	125*	123*	132	136	138	137	144	137	137	136	137·3	32
135	133	130	133	132	131	134	136	137	135	138	138	134·7	13
133	138	142	140	137	135	137	136	138	138	138	136	135·8	12
136	138	135	134	135	130	128	130	134	138	141	138	137·8	41
131	135	137	138	135	132	131	133	135	139	136	136	134·5	11
143	143	144	142	137	135	136	137	139	139	139	139	137·1	15
141	140	135	134	135	137	139	140	141	141	142	142	137·5	14
140	140	138	136	136	143	142	142	143	142	144	145	140·5	12
136	136	135	135	138	143	145*	142	141	140	141	140	141·2	12
142	137	130	128	133	133	136	132	134	137	134	138	138·1	20
143	142	140	137	135	136	136	137	137	138	141	140	138·2	12
138	135	127*	128	131	134	134	134	132	133	145	132	137·4	19
140	138	138	136	136	136	138	138	136	138	139	138	137·5	15
134	132	132	134	137	138	138	137	138	138	138	138	137·4	10
137	139	137	152*	143	151*	138	110*	114*	114*	122*	118*	135·0	43
116*	119*	116*	116*	109*	115*	108*	118*	115*	111*	110*	111*	121·6	36
127*	133	118*	115*	113*	113*	116*	129	118*	125*	126*	133	122·5	22
136·9	136·6	134·2	134·2	133·0	133·5	133·8	133·9	134·6	135·5	136·3	136·3	136·10	
138·6	137·6	137·0	135·3	135·5	135·9	135·6	136·0	137·8	138·0	137·7	137·8		

DIFFERENTIAL MEASURES—

Hourly readings from the photographic traces of the bifilar

[Local mean time. 200 divisions plus tabular quantity, one division = 0·000109 in parts of H. All

AUGUST, 1883.

[For the explanation of these tables see pp. 53, 54.]

Day.	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	Noon.
1	132	138	132	133	134	135	131	124*	125*	134	135	138
2	129*	131	131	129*	130*	130*	129	127	125*	124*	123*	123*
3	132	132	131	130*	132	133	131	125	123*	122*	123*	124*
4	134	137	137	137	137	138	138	136	133	132	129	126*
5	141	139	140	141	144	144	142	137	135	138	136	133
6	140	140	139	138	135	137	133	127	128	132	129	130
7	135	137	138	137	138	136	134	129	131	131	134	138
8	134	134	135	136	136	135	132	132	133	133	130	128
9	137	137	138	137	137	139	137	135	139	137	137	134
10	140	139	141	145	143	147	145	140	138	136	135	139
11	137	140	140	138	138	140	141	136	136	139	139	139
12	141	141	141	141	140	140	137	131	134	137	141	140
13	141	141	141	141	140	140	138	134	130	132	135	136
14	136	135	136	138	138	136	132	128	129	133	133	133
15	144	161*	153*	156*	147	149	143	139	140	142	140	142
16	144	144	[143	142	142	141	138	134	133]	134	135	139
17	144	144	144	143	144	146	140	134	137	140	148*	152*
18	148	143	143	145	144	139	135	134	139	137	136	134
19	138	138	138	137	137	139	138	136	137	136	134	135
20	140	140	139	139	139	139	136	133	129	130	134	140
21	142	142	142	144	144	143	140	136	134	136	140	140
22	142	141	142	145	145	145	143	135	132	135	136	137
23	144	141	146	144	144	145	142	142	139	137	136	133
24	141	145	144	142	142	143	139	135	133	136	138	141
25	142	141	141	142	142	142	138	133	132	136	135	138
26	142	142	142	142	143	143	140	135	131	130	133	136
27	142	143	144	143	143	143	139	136	140	149*	145	138
28	144	145	145	143	143	144	146	150*	157*	154*	153*	154*
29	142	143	143	142	142	144	141	136	135	136	136	134
30	143	143	142	144	144	146	148*	149*	150*	148*	146*	141
31	142	143	143	143	143	142	138	136	140	140	144	147*
Monthly mean	139·8	140·6	140·5	140·5	140·3	140·7	138·2	134·6	134·7	136·0	136·4	136·8
Normal	140·1	140·0	140·0	140·8	140·7	141·1	137·9	134·0	134·5	135·3	136·0	131·6

HORIZONTAL INTENSITY—Continued.

magnetometer of the Los Angeles Magnetic Observatory.

readings referred to standard temperature of magnet. Increasing numbers indicate increasing force.]

AUGUST, 1883.

13^h	14^h	15^h	16^h	17^h	18^h	19^h	20^h	21^h	22^h	23^h	Mid-night.	Daily mean.	Daily range.
133	128*	127*	132	122*	130*	117*	124*	124*	124*	133	128*	129·7	22d
124*	124*	125*	126*	125*	125*	124*	130*	131	132	131	132	127·5	10
126*	127*	126*	130	133	133	134	135	134	135	134	137	130·1	16
129	133	135	138	137	138	138	138	138	140	142	140	135·8	16
132	133	138	138	139	139	134	134	134	135	138	145	137·9	14
127*	126*	125*	130	133	131	134	135	136	138	140	135	133·3	16
137	140	136	135	135	122*	114*	125*	133	131	131	134	133·0	27
128*	128*	130*	132	133	133	134	135	136	134	136	138	133·1	12
133	134	135	137	138	140	141	139	140	139	140	140	137·5	9
142	143	140	138	137	134	138	135	133	131	138	136	138·9	16
135	135	135	134	135	138	137	138	141	140	140	140	138·0	8
138	137	136	137	138	138	140	141	142	141	141	141	138·9	12
133	132	136	138	138	138	137	138	136	136	135	135	136·7	11
134	137	131	132	129	142	143	144	144	144	143	145	136·5	18
141	142	142	142	142	143	144	144	144	144	144	144	144·7	21
143	143	145	143	142	144	145	145	145	145	144	145	[141·6]	[11]
150*	147	143	141	141	143	143	143	145	145	150*	146	143·9	20
133	128*	129*	129	126*	125*	134	134	133	138	139	138	136·0	25
138	149*	151*	153*	143	143	142	141	143	141	143	142	140·5	21
144	146	146	143	142	141	141	141	141	141	141	141	139·4	17
141	141	140	138	136	138	139	140	140	142	144	143	140·2	12
139	135	139	136	134	142	143	143	143	142	142	142	139·9	15
142	135	138	139	135	132	137	138	142	137	139	141	139·5	14
141	142	141	141	141	141	140	141	141	141	140	142	140·5	12
139	142	142	141	140	140	142	142	143	142	142	143	140·0	11
137	138	138	138	138	139	141	142	142	143	143	142	139·2	14
141	151*	151*	152*	147*	147	145	145	144	144	143	144	144·1	16
149*	148*	147	142	140	141	142	143	143	143	143	143	145·9	18
136	139	144	142	143	144	142	142	143	142	140	140	140·5	12
139	140	138	138	140	141	142	142	142	143	141	142	143·0	14
147*	148*	149*	148*	143	141	142	141	140	137	135	139	142·1	12
137·1	137·8	138·0	138·2	136·9	137·6	137·7	138·7	139·2	139·0	139·8	140·1	138·30	
137·5	138·8	139·3	137·2	137·9	139·4	139·8	140·0	139·7	139·5	139·5	140·5		

DIFFERENTIAL MEASURES—

Hourly readings from the photographic traces of the bifilar

[Local mean time. 200 divisions plus tabular quantity, one division = 0·000109 in parts of H. All

SEPTEMBER, 1883.

[For the explanation of these tables see pp. 53, 54.]

Day.	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	Noon.
1	140	140	140	142	144*	142	138	131	129	130	133	136
2	140	143	142	141	141	143*	141*	138*	139*	144*	143*	143*
3	144*	143	140	142	142*	141	139	136*	134	134	134	137*
4	142	140	144	142	140	141	139	135*	131	134	137*	138*
5	136	137	139	138	138	139	139	135*	137*	143*	143*	136
6	126	130	132	137	133	136	136	130	131	133	137*	138*
7	140	141	142	142	143*	144*	139	136*	138*	139*	137*	137*
8	139	139	140	140	140	142	142*	137*	135*	137*	137*	137*
9	141	141	141	141	142*	142	142*	138*	134	131	132	133
10	145*	137	141	141	144*	144*	141*	138*	136*	136*	136*	138*
11	139	139	139	140	140	139	135	132	132	135	137*	134
12	137	138	139	139	138	139	138	136*	134	134	134	136
13	139	138	140	140	137	139	133	116	127	130	132	132
14	136	137	136	136	137	134	127	126	126	125	127	131
15	139	138	139	139	138	136	130	125	124	126	128	131
16	100*	108*	89*	110*	101*	103*	97*	98*	95*	101*	97*	105*
17	110*	108*	108*	111*	107*	114*	114*	115*	113*	113*	112*	113*
18	121*	121*	122*	123*	122*	127	119*	122	127	121	115*	117*
19	124*	125*	127	127	124	125	125	122	118	116*	116*	117*
20	132	131	129	128	129	128	125	121	119	120	121	120
21	130	130	132	130	130	130	126	121	117	116*	118	121
22	131	130	130	130	131	131	128	124	120	117	116*	121
23	129	130	129	130	131	133	130	131	128	125	125	122
24	128	128	128	127	128	129	128	126	122	120	118	119*
25	125	123*	125*	126*	125	127	124	123	124	122	123	125
26	121*	123*	124*	124*	124	125	122	120	116*	116*	118	116*
27	127	129	128	128	128	129	124	121	119	120	120	120
28	127	129	127	131	131	131	129	122	122	121	120	119*
29	127	128	128	128	129	131	130	127	128	126	124	126
30	130	127	132	131	130	128	123	121	118	118	116	117
Monthly mean	131·5	131·7	131.7	132·8	132·2	133·1	130·1	126·8	125·8	126·1	126·2	127·2
Normal	133·9	135·1	135·4	135·6	132·8	133·8	130·7	124·3	125·6	126·1	125·4	127·2

HORIZONTAL INTENSITY—Continued.

magnetometer of the Los Angeles Magnetic Observatory.

readings referred to standard temperature of magnet. Increasing numbers indicate increasing force.]

SEPTEMBER, 1883.

13^h	14^h	15^h	16^h	17^h	18^h	19^h	20^h	21^h	22^h	23^h	Mid-night.	Daily mean.	Daily range.
139*	136	138	136	138	140*	139	143*	145*	144*	145*	139*	138·6	17^d
140*	144*	140	137	132	132	135	133	132	138*	142*	142*	139·4	20
138*	134	141*	142*	145*	142*	141*	143*	142*	140*	138	137	139·5	12
139*	141*	140	138	134	128	126	132	131	130	132	131	136·0	18
136	136	135	130	125	130	129	126	120*	124	123	123	133·2	25
138*	137	137	136	134	133	135	137	137	137	137	138	134·8	13
135	132	136	137	138	138	138	139	138	139*	139*	140*	138·6	12
137*	139*	140	141*	138	138	139	139	139	140*	141*	141*	139·0	8
134	135	140	138	139	140*	134	143*	144*	140*	142*	141*	138·7	15
140*	140*	139	138	138	138	139	139	139	139*	140*	140*	139·4	10
136	140*	142*	143*	141*	140*	142*	140	137	135	147*	135	138·3	17
138*	140*	138	146*	144*	142*	143*	132	134	140*	140*	140*	138·3	17
134	129	130	133	132	134	134	135	134	134	135	135	133·4	25
130	130	136	139	137	137	138	139	138	138*	139*	138	134·0	14
133	136	141*	137	137	139	159*	160*	125	83*	96*	98*	130·7	116
112*	128	126	121*	117*	83*	99*	84*	90*	87*	92*	105*	102·0	57
112*	115*	116*	116*	117*	120*	119*	119*	120*	120	120*	121	114·7	18
126	127	128	124	117*	118*	115*	120*	128	129	124	129	122·6	20
122	122	124	124	121*	122	124	127	127	128	129	127	123·5	14
123	126	128	128	128	128	127	127	129	130	130	130	126·5	13
123	128	128	129	128	129	128	130	129	131	128	128	126·7	17
123	125	126	127	128	128	128	121*	126	128	129	129	126·1	16
125	130	130	130	130	130	129	129	124	127	128	129	128·5	13
122	121	123	117*	114*	116*	118*	114*	117*	116*	120*	121	121·7	15
127	122	118*	120*	118*	120*	116*	118*	112*	111*	115*	115*	121·0	19
123	127	125	124	123	124	125	126	125	126	126	128	123·0	12
123	124	127	126	127	128	126	127	132	132	130	127	125·9	14
121	124	126	125	125	126	127	127	120*	125	126	133	125·6	15
118*	116*	121*	126	123	126	122	127	126	128	128	128	125·9	16
120	122	124	125	125	126	128	128	129	127	130	129	125·2	16
128·9	130·2	131·4	131·1	129·8	129·2	130·1	130·1	129·0	128·2	129·7	129·9	129·70	
127·2	128·7	131·8	131·2	131·4	130·7	131·0	132·0	131·3	128·9	129·6	129·8		

DIFFERENTIAL MEASURES—

Hourly readings from the photographic traces of the bifilar

[Local mean time. 200 divisions plus tabular quantity, one division = 0.000109 in parts of H. All

OCTOBER, 1883.

[For the explanation of these tables see pp. 53, 54.]

Day.	1^h	2^h	3^h	4^h	5^h	6^h	7^h	8^h	9^h	10^h	11^h	Noon.
1	129	129	130	130	130	128	124	120	121	123	123	124
2	130	130	130	130	130	130	127	122	119	118	120	120
3	129	130	131	130	131	131	129	125	124	124	126	127
4	129	130	130	131	130	130	129	128	127	127	126	126
5	128	127	131	129	132	129	128	105*	107*	104*	109*	111*
6	126	122	122	123	121	123	121	116	120	120	121	124
7	124	127	128	129	126	125	125	124	123	123	123	121
8	129	128	131	131	128	128	123	122	123	124	124	126
9	128	128	130	129	129	128	125	123	124	125	123	124
10	129	130	131	131	130	129	128	128	125	124	121	121
11	131	131	132	132	132	131	129	123	119	121	119	122
12	127	128	129	129	129	128	125	120	118	117	118	120
13	127	128	128	129	127	125	121	116	114	116	119	117
14	124	126	126	126	127	124	121	117	114	114	114	116
15	131	128	128	129	129	124	122	111*	110*	112	116	117
16	120	120	125	123	124	124	123	122	129	126	119	122
17	118	119	119*	118*	120	120	118	116	115	114	115	114
18	122	124	126	129	125	124	120	114	111*	112	107*	107*
19	127	127	128	131	130	130	126	121	116	116	117	112*
20	123	124	125	124	128	129	128	124	122	114	112	115
21	125	126	126	127	127	126	121	117	117	117	117	118
22	124	123	125	123	127	126	126	122	119	120	119	119
23	125	127	126	128	127	126	127	126	124	124	125	126
24	126	128	128	129	128	128	127	126	127	127	128	128
25	130	131	131	131	130	129	128	128	127	127	129	129
26	123	126	129	129	127	129	126	126	124	123	123	124
27	126	128	128	128	128	128	125	121	119	119	121	122
28	129	129	129	131	130	130	129	126	122	122	123	124
29	131	131	131	131	131	130	128	124	122	123	126	127
30	133	133	133	132	133	132	128	122	119	119	120	121
31	131	131	130	131	131	131	131	124	121	121	121	122
Monthly mean	126·9	127·4	128·3	128·5	128·3	127·6	125·4	121·3	120·1	119·9	120·1	120·8
Normal	126·9	127·4	128·6	128·8	128·3	127·6	125·4	122·2	121·2	120·4	121·0	122·0

HORIZONTAL INTENSITY—Continued.

magnetometer of the Los Angeles Magnetic Observatory.

readings referred to standard temperature of magnet. Increasing numbers indicate increasing force.]

OCTOBER, 1883.

13^h	14^h	15^h	16^h	17^h	18^h	19^h	20^h	21^h	22^h	23^h	Mid-night.	Daily mean.	Daily range.
125	127	130	129	127	127	129	128	129	130	130	130	127·2	11d
123	125	126	125	124	127	128	129	128	125	124	126	125·7	12
127	127	127	128	127	128	129	129	129	128	129	129	128·1	8
125	129	129	130	139*	138*	135	132	134	133	134	136	130·7	15
110*	103*	103*	111*	112*	118	116*	108*	114*	117*	118*	124	116·4	35
123	120	115*	114*	112*	116*	121	124	127	126	121	123	120·9	16
124	127	127	124	123	125	126	127	128	128	127	127	125·5	8
124	119	124	125	124	126	126	128	128	128	128	128	126·0	13
126	125	126	126	127	129	129	130	131	130	129	130	127·3	8
122	124	127	127	128	129	129	130	131	131	130	129	127·7	11
124	127	129	130	130	130	130	130	129	129	129	130	127·9	14
120	121	126	124	123	116*	123	124	126	125	125	125	123·6	14
124	126	125	125	124	126	125	126	125	124	121	123	123·4	12
123	127	128	128	127	123	127	128	128	128	128	126	123·8	16
114*	111*	109*	110*	112*	108*	110*	113*	120	111*	109*	115*	116·6	24
127	132	114*	123	111*	114*	111*	104*	91*	107*	107*	121	118·3	48
116	117	117*	118	117*	119	122	124	119	114*	112*	116*	117·4	12
114*	119	120	124	124	125	123	124	129	129	126	127	121·0	22
118	124	123	120	123	122	116*	114*	126	124	121	122	122·3	20
125	125	123	123	122	124	124	124	124	124	124	125	123·1	18
122	125	126	126	126	126	128	125	125	123	122	123	123·4	11
121	122	122	123	124	126	126	125	126	126	127	126	123·6	8
124	124	124	125	125	127	128	128	128	128	133	123	126·2	10
130	129	129	129	128	126	128	128	128	128	130	130	128·0	5
131	132	130	130	127	128	128	131	128	130	129	135	129·5	10
127	129	129	130	126	125	128	128	126	127	127	128	126·6	7
[126]	128	126	127	127	129	130	130	130	130	129	128	[126·4]	12
128	130	129	129	130	131	132	131	132	130	132	131	128·7	10
132	133	132	132	132	132	133	134	133	131	133	133	130·2	12
122	125	127	128	128	132	132	132	132	132	132	131	128·3	14
125	128	130	130	130	132	132	132	132	130	130	131	128·6	12
123·3	124·5	124·3	124·9	124·5	125·3	125·9	125·8	126·3	126·0	125·7	126·8	124·90	
124·5	125·7	126·7	126·4	126·2	126·6	127·8	128·2	128·0	128·0	127·8	127·6		

DIFFERENTIAL MEASURES—

Hourly readings from the photographic traces of the bifilar

[Local mean time. 200 divisions plus tabular quantity, one division = 0·000109 in parts of H. All

NOVEMBER, 1883.

[For the explanation of these tables see pp. 53, 54.]

Day.	1^h	2^h	3^h	4^h	5^h	6^h	7^h	8^h	9^h	10^h	11^h	Noon.
1	130	130	131	131	132	132	130	124	118	120	126	127
2	105*	104*	114*	120	119	121	117	116	115	117	118	121
3	111*	120	115*	118	117	114*	116	116	115	111	111	112
4	128	127	124	123	127	123	121	118	116	114	113	115
5	126	126	125	124	126	126	125	124	122	120	115	120
6	125	126	126	126	127	126	127	126	126	126	125	126
7	127	127	127	127	129	128	127	124	122	121	120	121
8	129	129	129	130	130	130	127	124	121	122	120	123
9	129	129	130	131	130	130	129	126	124	122	122	124
10	130	130	131	131	131	131	130	128	125	123	124	126
11	132	130	132	133	130	130	133	132*	130*	127	127	128
12	126	126	129	129	131	133	133	132*	129*	126	125	128
13	126	126	126	127	128	128	129	128	126	126	125	123
14	120	121	127	125	126	126	125	124	123	120	120	120
15	125	126	126	126	127	128	127	124	120	118	119	122
16	126	126	126	126	127	128	126	125	122	122	123	125
17	129	129	127	125	125	125	124	124	122	121	121	120
18	126	127	128	128	127	128	128	125	122	120	118	118
19	127	128	126	128	127	127	126	122	119	119	118	121
20	116*	125	118	130	118	122	126	125	124	111	109*	108*
21	114*	115*	118	119	119	119	118	111*	106*	105*	106*	109*
22	100*	89*	92*	109*	119	102*	94*	92*	100*	91*	95*	100*
23	101*	106*	110*	117	109*	111*	112*	112*	111	109*	107*	110*
24	113*	114*	114*	116	115*	115*	116	114	110*	105*	102*	104*
25	119	120	121	121	122	123	121	118	114	113	111	113
26	120	120	120	121	121	122	122	119	118	115	116	117
27	117	118	118	120	126	119	123	122	116	115	113	113
28	115*	118	120	122	122	121	122	119	113	113	114	115
29	119	119	119	119	119	120	122	121	119	114	113	114
30	118	119	119	119	120	120	122	119	116	114	113	114
Monthly mean	121·0	121·7	122·3	124·0	124·2	123·6	123·3	121·1	118·8	116·7	116·3	117·9
Normal	125·2	124·9	124·9	124·6	125·1	125·6	124·7	122·2	119·6	118·8	118·8	120·2

HORIZONTAL INTENSITY—Continued.

magnetometer of the Los Angeles Magnetic Observatory.

readings referred to standard temperature of magnet. Increasing numbers indicate increasing force.]

NOVEMBER, 1883.

13^h	14^h	15^h	16^h	17^h	18^h	19^h	20^h	21^h	22^h	23^h	Mid-night.	Daily mean.	Daily range.
122	114	113	117	119	112*	107*	112	113	110*	112*	103*	120·2	30^d
121	123	116	112*	110*	97*	84*	100*	90*	92*	109*	109*	110·4	39
114	117	118	120	124	124	121	122	122	123	122	124	117·8	15
116	118	121	122	122	123	124	124	124	128	126	126	121·8	15
124	126	126	120	121	120	123	127	125	123	125	125	123·5	13
126	126	129	127	126	124	124	125	127	126	126	126	126·0	6
126	126	123	126	128	129	129	129*	128	127	130	131	126·3	12
125	124	127	129	130	130	130	130*	131*	130	130	129	127·5	11
126	129	130	128	128	131	131	130*	131*	130	130	130	128·3	10
128	128	131*	128	128	129	129	131*	131*	132*	130	128	128·9	10
132*	130	131*	130	132*	134*	133*	131*	128	131	124	126	130·3	11
129	125	124	117	122	123	122	122	125	123	123	125	126·1	18
124	125	124	124	123	119	120	119	119	124	123	120	124·3	10
120	121	121	120	119	120	121	121	121	122	124	126	122·2	9
125	126	126	128	128	128	127	126	126	126	127	127	125·3	12
126	128	128	129	130	129	129	129*	129	128	128	127	126·8	8
121	122	123	124	125	126	126	126	127	126	127	127	124·7	10
120	127	129	128	128	128	129	129*	130	126	128	128	126·0	12
121	118	120	117	111*	121	123	119	116	119	122	129	121·8	20
106*	108*	112*	116	115	111*	110*	106*	110*	114	114	114*	115·3	25
108*	113	116	116	120	121	117	111	119	116	105*	92*	113·0	52
99*	98*	98*	94*	89*	100*	89*	86*	86*	90*	99*	97*	96·2	43
117	114	108*	99*	107*	112*	113*	113	112*	113*	114	114*	110·5	24
107*	109*	110*	114	115	117	117	117	117	117	117	118	113·0	18
114	116	117	118	118	121	120	120	119	120	120	120	118·3	12
119	122	122	121	120	123	124	122	121	119	121	118	120·1	10
115	119	119	120	119	119	120	116	116	117	116	115*	118.0	15
117	117	117	114	118	118	118	117	117	119	116	117	117·5	9
115	117	118	116	117	119	118	118	119	118	117	117	117·8	10
117	118	116	117	115	116	115	112	113	117	116	114*	116·6	12
119·3	120·1	120·4	119·7	120·2	120·8	119·8	119·7	119·7	120·2	120·8	120·1	120·49	
121·1	121·8	121·8	121·7	122·3	123·2	123·2	119·4	121·8	122·8	123·0	124·7		

DIFFERENTIAL MEASURES—

Hourly readings from the photographic traces of the bifilar

[Local mean time. 200 divisions plus tabular quantity, one division = 0·000109 in parts of H. All

DECEMBER, 1883.

[For the explanation of these tables see pp. 53, 54.]

Day.	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	Noon.
1	116	118	119	121	122	122	125	122	116	110	108	111
2	110*	113	114	115	117	118	118	118	116	111	106	107
3	116	117	118	119	118	119	119	117	116	110	107	107
4	120	121	122	122	122	123	123	122	121	118	115	118
5	122	123	123	123	123	124	122	119	116	112	112	114
6	123	123	124	125	125	125	124	122	119	115	113	115
7	123	124	124	124	124	124	123	122	118	112	111	114
8	126	125	126	126	127	127	127	124	123	121	122	118
9	120	121	121	119	125	124	123	120	118	112	110	110
10	118	117	119	120	120	121	122	120	116	114	116	118
11	122	119	119	118	124	124	125	126	124	121	120	118
12	117	121	120	118	122	121	123	122	122	120	116	114
13	116	117	118	120	119	120	119	117	118	117	113	112
14	120	120	125	122	122	123	122	123	119	123	117	115
15	120	119	119	120	120	121	122	122	120	116	114	116
16	121	121	120	121	121	122	123	123	123	122	120	116
17	120	121	122	122	122	123	122	120	119	114	108	103*
18	112	117	117	117	119	120	119	118	117	116	109	108
19	119	118	121	119	120	122	121	123	121	118	114	110
20	119	119	120	120	121	122	129	130	130*	129*	123*	117
21	125	125	125	125	125	127	127	125	121	118	116	116
22	122	124	125	126	128	127	127	126	120	112	109	111
23	122	123	124	124	124	126	127	125	122	117	113	114
24	125	125	127	128	130	131	133*	132*	131*	126*	121	120
25	123	122	127	127	126	127	127	126	120	116	116	113
26	122	118	119	122	121	122	123	123	122	117	114	115
27	119	119	121	120	120	122	122	122	123	121	116	115
28	115	116	117	119	124	126	120	117	117	112	109	111
29	116	117	118	121	122	122	124	124	120	114	110	110
30	119	120	121	121	122	122	122	122	120	113	110	110
31	121	123	124	124	124	125	124	120	121	116	116	119
Monthly mean	119·6	120·2	121·3	121·5	122·5	123·3	123·5	122·3	120·3	116·5	113·7	113·4
Normal	120·0	120·2	121·3	121·5	122·5	123·3	123·1	122·0	119·6	115·8	113·4	113·7

HORIZONTAL INTENSITY—Continued.

magnetometer of the Los Angeles Magnetic Observatory.

readings referred to standard temperature of magnet. Increasing numbers indicate increasing force.]

DECEMBER, 1883.

13h	14h	15h	16h	17h	18h	19h	20h	21h	22h	23h	Mid-night.	Daily mean.	Daily range.
114	114	110*	106*	110*	109*	103*	98*	101*	100*	104*	105*	111·8	28d
110	106*	116	116	117	117	118	118	117	118	119	116	114·6	14
107	112	115	118	119	119	120	121	122	121	121	120	116·6	15
118	118	121	122	123	124	124	123	123	122	122	122	121·2	10
117	119	122	123	124	124	124	123	124	123	123	122	120·9	13
117	117	120	124	124	125	125	125	124	124	124	124	121·9	12
115	120	123	124	125	126	126	126	126	125	125	126	122·1	15
117	120	121	123	117	119	119	122	122	119	117	125	122·2	12
113	114	116	119	118	120	119	119	119	118	116	116	117·9	16
120	121	119	119	124	123	124	127	121	122	120	121	120·1	15
121	122	120	121	122	116	123	122	120	120	122	119	121·2	11
112	113	109*	111*	114	113	110*	109*	113	116	115	115	116·1	15
114	115	116	117	118	118	120	118	118	112	115	118	116·9	10
115	119	117	115	116	118	117	117	116	118	118	119	119·0	12
117	119	119	120	121	121	121	121	121	121	120	121	119·6	9
121	123	125	125	124	124	122	122	122	122	122	122	122·0	10
106*	105*	116	116	118	114	117	117	114	114	109*	119	115·7	20
112	114	117	115	116	117	117	116	117	118	118	119	116·0	13
110	109*	115	119	119	118	119	119	119	119	119	120	118·0	14
120	129*	126	128	125	124	123	121	125	126	126	125	124·0	14
116	118	121	123	124	124	124	124	123	123	123	123	122·5	11
116	120	123	124	124	123	125	124	125	124	122	122	122·0	20
116	120	122	123	127	126	124	123	125	124	125	125	122·5	14
126*	127	128	124	126	124	122	123	118	121	120	122	125·4	16
115	116	118	117	115	117	117	119	116	118	116	114	119·5	15
118	121	121	120	122	119	117	113	114	114	114	117	118·7	10
120	121	121	118	113	118	115	112	115	114	112	114	118·0	12
114	116	119	121	121	120	120	119	118	121	117	116	117·7	18
112	117	117	120	119	118	118	118	118	118	118	120	118·0	14
114	120	123	122	121	121	121	121	122	121	121	121	119·6	14
120	121	122	126	125	126	125	131*	125	127	125	125	123·1	15
115·6	117·6	119·3	120·0	120·4	120·2	120·0	119·7	119·5	119·5	119·0	119·8	119·52	-
115·6	118·4	119·9	120·8	120·7	120·5	120·9	120·5	120·1	120·1	119·8	120·3		

DIFFERENTIAL MEASURES—

Hourly readings from the photographic traces of the bifilar

[Local mean time. 200 divisions plus tabular quantity, one division = 0·000109 in parts of H. All

JANUARY, 1884.

[For the explanation of these tables see pp. 53, 51.]

Day.	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	Noon.
1	126	126	126	126	126	126	125	123	117	115	108	110
2	120	121	122	121	122	122	122	121	116	113	110	114
3	127	127	127	126	127	127	126	125	120	110	109	110
4	126	126	126	126	126	126	126	125	125	118	113	113
5	119	121	121	121	123	124	125	124	121	115	108	108
6	120	121	122	123	123	124	124	124	121	118	113	111
7	124	124	125	126	127	130	129	129	124	117	114	115
8	125†	124†	126†	122†	127†	124†	123†	121†	119†	110	107	111
9	122	123	122	122	123	123	124	123	121	118	113	116
10	123	124	124	124	125	127	130	128	120	117	114	114
11	119	123	123	124	124	124	124	123	119	113	110	112
12	115	118	120	118	127	124	122	120	110*	105*	103	108
13	119	118	121	119	118	119	119	118	119	113	111	111
14	122	122	122	123	123	124	125	123	119	112	108	110
15	114	116	117	120	123	122	121	120	117	110	109	111
16	120	121	119	119	119	121	122	120	114	105*	104	105
17	121	120	123	124	124	126	127	126	122	117	113	111
18	125	125	126	126	126	127	125	123	122	119	119	118
19	118	126	119	119	121	120	121	120	120	116	111	108
20	123	123	123	124	124	123	124	123	121	115	108	110
21	120	121	123	123	125	125	125	124	121	114	108	104
22	122	124	124	124	124	125	125	125	122	116	111	113
23	121	125	125	124	124	123	124	123	120	115	110	110
24	123	124	123	124	125	125	125	122	120	114	111	114
25	123	124	124	126	126	126	126	126	125	121	114	114
26	108*	113*	124	116	118	117	118	117	116	111	104	110
27	117	120	119	119	119	120	120	120	120	121	115	114
28	119	122	120	120	120	121	122	123	121	117	112	114
29	122	122	122	122	122	122	123	122	120	118	113	112
30	123	123	123	123	124	125	126	126	127	124	115	113
31	126†	126†	125†	125†	125†	125†	125†	126†	124	122	117	115
Monthly mean	121·0	122·4	122·8	122·5	123·5	123·8	124·0	123·1	120·1	115·1	110·8	111·6
Normal	121·5	122·7	122·8	122·5	123·5	123·8	124·0	123·1	120·4	115·8	110·8	111·6

† Corrected by observer for disturbing effect of red lantern.

HORIZONTAL INTENSITY—Continued.

magnetometer of the Los Angeles Magnetic Observatory.

readings referred to standard temperature of magnet. Increasing numbers indicate increasing force.]

JANUARY, 1884.

13^h	14^h	15^h	16^h	17^h	18^h	19^h	20^h	21^h	22^h	23^h	Mid-night.	Daily mean.
114	118	121	125	123	122	121	122	121	121	120	121	121·1d
119	122	126	131	129	129	128	128	127	128	127	127	122·7
115	121	126	129	128	128	128	126	127	127	126	126	123·7
115	121	128	130	128	128	127	124	121	118	118	117	123·0
111	117	119	122	123	124	125	124	124	122	121	120	120·1
114	117	121	124	125	125	126	125	125	124	124	124	121·6
120	125	127	128	127	128	126	123	124	122	121†	123†	124·1
114	118	120	121	120	116	118	121	121	121	120	122	119·6
120	122	123	123	121	123	124	125	123	124	123	123	121·8
116	118	120	127	123	124	117	119	117	114	119	120	121·0
113	114	116	115	114	113*	114	115	114	116	114	114	117·1
109	114	118	118	114	111*	115	118	118	117	118	118	115·7
114	118	121	120	120	120	120	121	122	122	122	122	118·6
115†	121†	126†	124†	119†	120	120	118	117	116	117	115	119·2
114	117	119	118	118	120	119	120	120	119	120	120	117·7
109	115	120	123	123	121	121	122	122	121	122	121	117·9
113	117	123	124	123	122	123	123	123	125	124	124	121·6
118	123	125	126	123	112*	115	116	115	115	116	120	121·0
108	111	115	120	121	122	122	123	123	124	123	123	118·9
112	113	120	124	125	126	126	121	119	122	121	120	120·4
107	110	114	119	122	123	122	122	122	121	120	121	119·0
116†	119	120	119	120	120	120	121	122	124	123	122	120·9
111	116	115	118	121	123	123	123	122	123	123	123	120·2
118	121	124	125	124	124	124	124	124	124	124	124	122·1
116	121	124	116	117	123	123	117	110*	111*	114	124	120·5
114	115	119	118	119	119	120	118	116	116	119	117	115·9
116	117	117	116	118	119	119	120	120	118	118	119	118·4
116†	117†	119†	119†	120	120	121	121	122	122	122	122	119·7
116	116†	118	121†	120	120†	120†	120	120	121	121	123	119·8
118	118	120	119	122	125	126	126	125	125	126†	126†	122·8
115†	116	121	124	124	126	126	127	126	125	125	128	123·5
114·4	117·7	120·8	122·1	121·7	121·8	121·9	121·7	121·0	120·9	121·0	121·6	120·31
114·4	117·7	120·8	122·1	121·7	122·9	121·9	121·7	121·4	121·2	121·0	121·6	

†Corrected by observer for disturbing effect of red lantern.

DIFFERENTIAL MEASURES—

Hourly readings from the photographic traces of the bifilar

[Local mean time. 200 divisions plus tabular quantity, one division = 0·000109 in parts of H. All

FEBRUARY, 1884.

[For the explanation of these tables see pp. 53, 54.]

Day.	1^h	2^h	3^h	4^h	5^h	6^h	7^h	8^h	9^h	10^h	11^h	Noon.
1	127	127	126	125	124	127	127	128	131	124	120	116
2	114	117	115*	123	120	122	128	126	124	120	113	108*
3	121	122	122	122	123	124	125	125	124	122	116	106*
4	118	118	119	121	124	124	128	126	134	131	123	116
5	123	122	122	123	126	124	126	130	130	125	121	116
6	120	121	122	122	122	122	124	126	124	122	120	114
7	123	122	122	124	124	124	124	126	125	124	120	118
8	117	117	119	124	123	125	126	128	125	124	121	110
9	117	120	121	126	124	122	123	124	125	124	121	117
10	124	124	125	126	126	128	130	132	132	129	126	122
11	124	124	125	128	128	126	128	130	130	126	121	118
12	124	125	125	126	126	127	127	128	127	125	124	125
13	127	128	127	127	128	128	128	129	128	124	120	117
14	130	131	132	132	132	132	133	134	133	128	125	124
15	132*	131	132	132	133	134	134	136	135	135*	130*	127*
16	128	127	128	129	128	129	130	131	131	126	125	123
17	126	125	127	129	129	129	130	128	130	129	125	121
18	124	125	132	123	124	125	127	127	128	125	120	117
19	124	126	124	126	126	126	127	128	128	125	120	117
20	125	126	126	126	127	128	130	128	127	125	122	120
21	128	127	126	127	127	128	129	129	129	127	125	119
22	126	126	128	129	130	130	132	133	131	129	126	122
23	125	128	125	126	129	130	126	126	133	127	122	113
24	117	119	119	118	121	121	120	125	118*	120	118	114
25	118	116	126	119	118	117	120	122	117*	118	114	110
26	121	121	122	123	122	124	124	125	123	118	118	117
27	121	121	121	122	122	123	124	125	121	117	115	115
28	121	121	122	120	122	123	123	123	121	120	117	115
29	120	120	123	122	120	121	122	124	124	129	113	121
Monthly mean	122·9	123·3	124·2	124·8	125·1	125·6	126·7	127·7	127·2	124·8	120·7	117·2
Normal	122·6	123·3	124·6	124·8	125·1	125·6	126·7	127·7	127·9	124·4	120·4	117·6

HORIZONTAL INTENSITY—Continued.

magnetometer of the Los Angeles Magnetic Observatory.

readings referred to standard temperature of magnet. Increasing numbers indicate increasing force.]

FEBRUARY, 1884.

13h	14h	15h	16h	17h	18h	19h	20h	21h	22h	23h	Mid-night.	Daily mean.
115†	121†	123†	125†	126†	128†	128†	124†	115†	123†	116†	114†	123·3d
109†	113†	114	118	119	121	120	121	121	120	121	120	118·6
107*	113	118	118	118	118	119	116	114	116	116	115	118·3
112	114	120	122	114	116	117	120	121	120	120	120	120·8
119	113	114	117	118	119	119	120	120	118	118	125	121·2
114	114	115	117	121	121	124	122	121	122	122	122	120·6
116	116	118	120	123	123	122	123	121	118	122	125	121·8
109	113	116	118	119	120	119	118	112*	118	118	118	119·0
114	113	116	118	121	121	122	121	121	122	122	123	120·8
115	114	116	120	123	125	126	125	124	124	123	122	124·2
119	121	123	124	125	125	125	124	122	123	123	124	124·4
123	121	122	124	126	127	127	126	127	128	128	128	125·7
117	119	123	126	125	126	126	126	126	126	127	129	125·3
126*	126	127	128	129	129	130	130	130	130	131	132*	129·8
127*	128*	128*	128	129	129	128	126	124	124	124	125	129·6
121	122	122	122	123	125	124	125	125	126	124	126	125·9
121	123	125	114	116	123	121	118	122	122	124	124	124·2
115	115	114	117	120	121	124	125	124	124	123	123	122·6
119	123	121	122	123	122	122	122	125	126	125	125	123·8
120	120	121	123	124	127	126	126	127	127	126	125	125·1
120	121	122	123	125	127	127	126	125	125	125	126	125·5
120	122	124	126	128	130	129	129	127	125	124	125	127·1
119	113	108*	114	96*	116	114	115	112*	112*	106*	119	118·9
111	114	114	116	118	120	120	120	118	113*	118	118	117·9
107*	109	112	113	118	117	119	120	121	121	121	122	117·3
118	115	115	116	117	118	119	119	119	122	121	121	119·9
114	115	116	118	117	118	120	120	121	121	121	120	119·5
116	117	119	120	120	119	118	119	117	119	121	119	119·7
125	107*	109*	113	113	100*	98*	92*	86*	82*	103*	104*	112·1
116·8	117·1	118·4	120·0	120·5	121·7	121·8	121·3	120·3	120·6	121·1	122·0	122·17
116·8	117·0	118·8	120·0	121·4	122·5	122·7	122·3	122·2	122·7	122·4	122·3	

† Corrected by observer for disturbing effect of red lantern.

DIFFERENTIAL MEASURES—

Hourly readings from the photographic traces of the bifilar

[Local mean time. 200 divisions plus tabular quantity, one division = 0·000109 in parts of H. All

MARCH, 1884.

[For the explanation of these tables see pp. 53, 54.]

Day.	1^h	2^h	3^h	4^h	5^h	6^h	7^h	8^h	9^h	10^h	11^h	Noon.
1	104*	109*	112*	111*	116*	116*	115*	114	109*	120	119	114
2	113*	117*	119	122	122	120	122	125	125	114	114	108*
3	116*	127	113*	128	117	118	120	124	124	128*	130*	125
4	122	123	123	124	124	125	126	129	128	128*	126	124
5	124	125	124	125	124	124	124	124	124	123	123	122
6	127	128	128	127	128	128	128	128	125	123	126	127
7	125	126	128	128	128	130	129	127	121	122	126	120
8	128	128	129	130	128	134	129	118	118	115	111	110
9	125	124	122	123	123	124	124	122	117	115	111	114
10	126	125	125	128	126	125	125	122	117	113	111	113
11	127	131	128	127	128	127	126	123	118	116	117	119
12	128	127	127	128	128	128	126	124	122	127	130*	135*
13	128	129	129	129	130	131	126	121	118	118	121	126
14	128	128	129	132	131	129	130	126	119	118	115	122
15	131	130	130	130	129	129	130	126	120	117	114	115
16	126	126	128	128	128	128	127	123	120	115	113	115
17	130	130	130	132	132	128	126	120	115	111	112	115
18	128	127	128	130	129	128	128	124	120	118	118	119
19	131	132	133	132	131	130	128	127	123	124	121	119
20	123	126	127	126	127	129	128	126	122	123	124	116
21	127	125	126	123	126	127	128	123	123	123	122	122
22	118	122	121	120	123	123	123	121	121	124	127	128*
23	121	122	124	122	125	126	125	122	126	125	127	124
24	127	133	132*	133	126	129	125	123	119	118	118	119
25	125	126	126	128	125	125	123	117	113	114	115	118
26	128	127	128	126	127	127*	123	119	115	116	114	115
27	128	130	138*	129	126	126	123	118	114	118	119	118
28	124	130	127	127	127	127	124	120	116	116	114	116
29	110*	114*	114*	116*	117	116*	119	116	114	113	111	107*
30	123	123	122	122	121	122	122	117	111	110	112	112
31	126	123	123	122	122	123	124	123	121	121	120	121
Monthly mean	124·1	125·6	125·6	126·1	125·6	125·9	125·0	122·3	119·3	118·9	118·7	118·6
Normal	126·1	126·9	126·6	126·9	125·9	126·6	125·4	122·3	119·6	118·3	118·0	118·5

HORIZONTAL INTENSITY—Continued.

magnetometer of the Los Angeles Magnetic Observatory.

readings referred to standard temperature of magnet. Increasing numbers indicate increasing force.]

MARCH, 1884.

13^h	14^h	15^h	16^h	17^h	18^h	19^h	20^h	21^h	22^h	23^h	Mid-night.	Daily mean.
106*	104*	105*	99*	109*	105*	103*	114*	118	117	116	118	$111·4^{d}$
111	108*	105*	106*	106*	106*	106*	99*	99*	117	111*	110*	112·3
118	122	121	121	119	116	116	116	115	114*	119	123	120·4
122	120	120	121	121	122	124	124	126	124	124	123	123·9
121	125	127	128	125	127	131	131	131	129	126	128	125·6
130*	130	131	131	132	132*	129	127	115	121	122	122	126·9
120	122	125	126	127	125	126	127	128	130	127	127	125·8
112	117	121	121	124	121	120	118	116	119	119	118	121·0
116	119	123	123	124	121	124	123	124	125	125	125	121·5
117	123	126	127	126	125	126	126	127	127	127	126	123·3
121	123	124	124	125	124	125	125	126	127	127	128	124·4
138*	139*	135*	131	129	126	127	128	128	129	129	129	129·1
129*	129	131	131	128	129	128	129	129	128	126	128	127·1
125	128	130	130	131	129	129	130	129	131	131	131	128·0
120	124	125	123	129	128	125	121	122	126	126	126	124·8
115	119	128	127	127	127	128	128	129	128	129	130	124·7
118	120	124	124	124	124	124	125	125	128	128	127	123·8
122	126	126	131	132	131	132	132	132	132	132	132	127·4
121	122	126	122	124	120	121	114*	117	116	120	123	124·0
114	123	126	118	112*	109*	115	113*	121	123	122	125	121·6
125	123	121	118	113*	117	117	118	117	114*	113*	115*	121·1
128*	128	129	125	122	121	122	124	123	121	123	123	123·3
120	128	128	127	126	124	121	124	125	126	126	124	124·5
122	125	120	123	121	118	122	124	123	126	130	124	124·2
122	125	124	125	124	121	121	121	121	122	125	126	122·2
118	123	128	125	121	121	126	126	126	127	127	129	123·4
122	123	125	124	122	121	122	122	120	131	119	121	123·3
110	106*	102*	111*	105*	106*	96*	110*	102*	94*	100*	110*	113·3
106*	110*	116	118	117	117	117	120	121	122	121	121	115·5
112	112*	114*	116	114*	115	115	118	120	124	119	120	117·3
121	119	116	118	120	118	119	125	123	120	121	122	121·3
119·4	121·5	122·6	122·4	121·9	120·8	121·2	122·0	121·9	123·2	122·9	123·7	122·47
118·6	123·4	124·7	124·2	124·8	122·6	123·3	124·3	123·4	124·9	124·5	125·0	

DIFFERENTIAL MEASURES—

Hourly readings from the photographic traces of the bifilar

[Local mean time. 200 divisions plus tabular quantity, one division = 0·000109 in parts of H. All

APRIL, 1884.

[For the explanation of these tables see pp. 53, 54.]

Day.	1^h	2^h	3^h	4^h	5^h	6^h	7^h	8^h	9^h	10^h	11^h	Noon.
1	129	123	124	124	124	128	125	128	129	127	123	117
2	128	126	128	127	128	128	128	130	131	131	129	127
3	127	128	127	127	128	128	125	125	125	123	120	119
4	129	129	132	137	130	129	126	123	121	122	124	124
5	128	129	130	128	131	131	129	124	121	125	126	128
6	132	131	130	133	131	131	129	125	121	119	119	121
7	132	131	133	133	134	133	131	129	129	131	128	128
8	130	131	131	131	131	131	130	129	130	127	125	123
9	133	132	[133]	[133]	[133]	[134]	[132]	[130]	[129]	[130]	128	128
10	132	140*	137	137	140*	138	130	135*	[131]	129	128	127
11	119*	123	124	128	125	128	126	124	119	117	116	118
12	125	125	125	128	128	126	125	123	123	121	120	120
13	128	128	131	129	130	130	127	124	124	124	125	127
14	131	133	131	132	132	133	128	125	128	128	127	127
15	125	126	126	127	127	128	126	125	126	130	131	128
16	129	126	129	129	126	131	129	125	124	123	123	121
17	130	129	135	130	131	132	125	123	119	127	126	126
18	125	125	130	128	124	134	131	125	122	118	112*	109*
19	125	126	128	130	127	125	125	123	121	117	115	116
20	124	124	128	127	128	127	122	125	124	124	122	121
21	126	127	126	126	126	126	123	122	123	124	122	121
22	128	128	128	128	128	127	122	119	119	[120]	[119]	[119]
23	[130]	[130]	[132]	[132]	[132]	[133]	[131]	[130]	[129]	130	131	130
24	128	128	130	130	134	135	132	129	127	125	115	122
25	122	120	122	118*	116*	117*	117*	117	119	123	121	122
26	126	127	128	130	128	130	129	130	130	128	120	117
27	131	128	129	129	129	129	126	125	124	125	125	126
28	128	131	130	130	130	130	128	127	126	127	127	128
29	130	129	129	129	129	130	128	126	123	124	122	124
30	132	132	133	135	135	132	128	125	129	132	128	128
Monthly mean	128·1	128·2	129·3	129·5	129·2	129·8	127·1	125·7	124·9	125·0	123·2	123·1
Normal	128·4	127·8	129·3	129·9	129·3	130·2	127·4	125·3	124·9	125·0	123·6	123·6

HORIZONTAL INTENSITY—Continued.

magnetometer of the Los Angeles Magnetic Observatory.

readings referred to standard temperature of magnet. Increasing numbers indicate increasing force.]

APRIL, 1884.

13^h	14^h	15^h	16^h	17^h	18^h	19^h	20^h	21^h	22^h	23^h	Mid-night.	Daily mean.
114*	116*	122	122	124	127	126	125	127	126	125	125	124·2[d]
123	122	124	123	127	127	124	126	127	123	128	128	126·8
119	124	123	125	125	125	126	124	125	128	126	128	125·0
125	127	129	131	130	129	129	130	131	130	130	130	128·2
130	129	129	131	130	129	130	129	131	132	131	130	128·8
127	129	131	130	128	128	129	132	132	132	132	131	128·5
131	134	135	134	132	131	133	133	134	133	133	132	132·0
127	130	132	132	131	129	130	130	131	131	132	132	129·8
130	130	129	130	130	130	131	131	132	132	133	132	[131·0]
130	123	128	122	126	130	127	129	126	125	123	122	[129·8]
121	122	122	124	124	123	125	125	124	123	126	129	123·1
122	124	127	128	127	125	126	126	128	129	129	129	125·4
129	127	130	130	128	123	128	130	131	131	131	132	128·2
129	130	125	121	120	120	116*	115*	117*	114*	120	130	125·5
130	131	129	124	116*	120	121	124	128	130	128	130	126·5
124	125	122	122	125	128	126	127	121	124	129	126	125·6
122	119	112*	126	112*	107*	110*	114*	128	117*	122	123	122·7
114*	117	119	123	117*	126	122	122	123	130	127	141*	123·5
116*	118	122	118	122	121	129	122	123	136	125	123	123·0
124	126	126	121	123	120	121	122	122	126	123	123	123·9
122	128	131	129	128	130	128	127	128	128	129	129	126·2
[121]	[122]	[124]	[124]	[123]	[123]	[124]	[125]	[127]	[127]	[127]	[129]	[124·2]
130	127	130	130	130	126	128	127	130	130	132	128	[129·9]
117	116*	120	111*	102*	108*	107*	110*	114*	118*	106*	108*	119·7
123	124	124	123	121	122	123	123	124	125	125	125	121·5
123	123	127	123	118	116*	119	122	124	125	126	130	125·0
127	125	126	126	123	126	127	124	126	127	128	129	126·7
126	133	132	133	130	125	125	127	128	128	129	130	128·7
128	132	132	132	130	130	130	130	131	131	132	132	128·9
126	128	128	130	133	129	130	132	135	123	113*	113*	128·7
124·3	125·4	126·3	125·9	124·5	124·4	125·0	125·4	126·9	127·1	126·7	127·6	126·36
125·4	126·0	126·8	126·4	126·5	126·0	126·6	126·8	127·7	128·3	127·9	128·4	

DIFFERENTIAL MEASURES—

Hourly readings from the photographic traces of the bifilar

[Local mean time. 200 divisions plus tabular quantity, one division = 0·000109 in parts of H. All

MAY, 1884.

[For the explanation of these tables see pp. 53, 54.]

Day.	1^h	2^h	3^h	4^h	5^h	6^h	7^h	8^h	9^h	10^h	11^h	Noon.
1	117*	116*	118*	116*	125	124*	122*	122	119*	117*	114*	119*
2	128	128	128	128	128	128	126	124	124	124*	124*	124*
3	131	133	131	131	132	133	131	128	130	130	129	130
4	133	131	133	133	134	134	130	126	129	132	132	130
5	132	134	131	132	132	132	[130	129	129]	130	132	132
6	132	130	133	133	135	136	135	136	141*	138	137	136
7	132	135	133	132	132	133	132	129	132	134	135	135
8	132	133	133	133	134	134	132	129	126	124*	126	127
9	134	133	133	134	133	132	131	129	129	131	130	129
10	135	134	131	132	133	130	132	137	133	134	132	127
11	129	138	132	131	131	131	129	124	121*	127	126	127
12	130	128	125	130	129	130	128	128	127	132	132	129
13	129	130	130	130	130	130	130	128	129	132	130	130
14	133	134	133	132	132	132	131	130	129	131	134	138
15	138	134	133	133	134	132	133	134	134	138	137	138
16	138	132	132	132	133	132	132	131	132	134	135	138
17	135	133	133	133	133	135	135	135	135	137	138	137
18	133	135	134	134	134	134	132	130	132	134	137	139
19	134	142	138	134	132	134	133	133	136	136	136	134
20	133	133	134	134	134	132	130	130	131	133	132	132
21	134	134	134	134	135	137	137	137	137	139	136	134
22	136	138	139	137	137	133	132	131	142*	141	134	127
23	130	129	128	129	128	130	128	129	130	132	130	128
24	133	132	131	130	131	131	128	125	128	132	132	132
25	135	134	134	133	133	133	131	127	132	134	135	137
26	137	136	137	138	138	138	134	132	133	135	136	138
27	136	135	135	136	136	138	136	132	129	132	139	138
28	139	136	136	136	136	136	133	132	136	136	133	134
29	134	135	134	136	139	137	136	135	136	138	136	136
30	134	134	133	134	134	135	134	134	136	137	136	136
31	140	140	141	139	141	142	143*	140*	139	138	140	137
Monthly mean	133·1	133·2	132·6	132·5	133·2	133·2	131·9	130·6	131·6	133·0	132·7	132·5
Normal	133·6	133·8	133·1	133·1	133·2	133·5	131·8	130·2	131·6	134·2	133·7	133·3

HORIZONTAL INTENSITY—Continued.

magnetometer of the Los Angeles Magnetic Observatory.

readings referred to standard temperature of magnet. Increasing numbers indicate increasing force.]

MAY, 1884.

13^h	14^h	15^h	16^h	17^h	18^h	19^h	20^h	21^h	22^h	23^h	Mid-night.	Daily mean.
121*	122*	121*	125	118*	125	126	126	127	128	127	128	121·8[d]
129	128	129	129	129	130	131	129	128	130	130	130	127·8
132	131	132	130	129	130	131	131	131	131	132	132	130·9
134	135	135	132	130	130	132	132	135	134	134	134	132·3
131	131	129	127	130	131	131	131	132	132	133	132	[131·0]
133	129	127	129	132	133	137	135	138	134	132	132	133·9
136	138	135	135	132	129	128	129	132	131	132	133	132·7
132	134	135	134	134	130	132	134	134	134	134	134	131·8
129	132	133	134	134	135	136	139	140	139	140	138	133·6
113*	121*	118*	125	129	129	128	130	126	126	132	134	129·2
134	136	126	125	116*	121	124	126	133	124	127	136	128·1
124*	126	129	128	129	129	129	130	129	130	132	130	128·9
130	132	131	132	129	127	130	131	132	134	134	131	130·5
136	132	131	129	128	131	132	132	135	132	134	135	132·3
135	135	132	130	130	129	125	126	131	131	132	137	133·0
136	135	133	130	128	129	130	132	132	132	132	132	132·6
137	135	130	131	129	131	132	130	130	132	131	132	133·3
140	139	136	132	127	126	126	128	129	128	133	133	132·7
133	133	129	126	127	126	129	131	132	132	133	132	132·7
131	133	133	132	132	132	133	133	133	133	134	134	132·5
134	130	129	130	131	132	131	132	133	133	134	134	133·8
134	136	128	128	122	119*	110*	113*	119*	127	130	130	130·1
127	132	130	128	128	128	130	131	132	134	134	130	129·8
137	135	132	130	128	129	131	132	132	133	134	135	131·4
140	142	140	137	134	134	134	134	134	134	134	136	134·6
140	140	137	134	131	131	132	131	132	134	133	135	135·1
139	138	138	134	131	130	133	136	135	134	135	135	135·0
137	137	136	134	133	132	133	134	135	134	134	135	134·9
137	136	133	132	134	133	134	133	132	134	135	135	135·0
135	134	135	134	133	133	134	134	134	134	139	138	134·8
138	135	135	130	130	131	130	130	126	129	125	128	135·3
133·0	133·3	131·5	130·5	129·3	129·5	130·1	130·8	131·7	131·8	132·7	133·2	131·98
134·5	134·1	132·3	130·5	130·1	129·8	130·8	131·4	132·1	131·8	132·7	133·2	

DIFFERENTIAL MEASURES—

Hourly readings from the photographic traces of the bifilar

[Local mean time. 200 divisions plus tabular quantity, one division = 0·000109 in parts of H. All

JUNE, 1884.

[For the explanation of these tables see pp. 53, 54.]

Day.	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	Noon.
1	127	123	124	124	125	125	125	127	129	129	128	128
2	123	128	127	128	128	136	137	147*	144*	138	130	134
3	128	130	128	129	128	131	131	130	132	131	131	132
4	130	129	130	131	132	129	127	126	131	138	140	143*
5	129	130	131	132	132	134	132	128	126	124	129	130
6	132	132	133	132	132	134	137	140*	140*	139	137	132
7	130	130	130	132	131	131	133	130	128	131	132	132
8	132	131	132	131	133	132	134	134	132	131	132	132
9	134	135	135	135	133	136	132	132	134	135	134	137
10	136	134	132	132	134	133	134	133	132	134	133	134
11	133	132	133	135	134	134	132	131	131	136	137	141
12	134	134	134	134	133	133	132	131	133	140	138	138
13	130	133	132	131	131	132	132	128	127	127	130	132
14	131	130	131	129	130	132	132	136	134	132	132	134
15	132	134	134	135	134	133	131	131	132	133	135	136
16	134	134	135	134	135	135	130	127	128	127	128	130
17	139	142*	139	139	140	145*	138	140*	134	134	133	132
18	139	141*	144*	145*	142*	142*	141*	138	138	142*	137	134
19	124	127	129	126	126	125	124	122	125	127	127	129
20	133	130	130	131	132	131	128	124	124	126	126	129
21	130	130	131	131	132	134	131	128	128	134	137	138
22	138	132	130	136	138	136	133	135	136	134	133	136
23	117*	144*	120*	127	130	126	121*	122	124	124	126	125
24	122*	124	124	130	126	130	130	128	127	129	129	128
25	127	129	132	128	130	131	130	129	130	128	126	126
26	131	131	131	131	132	131	130	128	127	130	130	131
27	129	130	132	130	130	132	132	129	130	131	127	127
28	134	134	138	138	137	137	138	132	130	134	131	134
29	133	130	131	132	133	133	133	135	135	136	134	136
30	133	134	134	136	135	133	128	127	130	130	133	132
Monthly mean	130·8	131·9	131·5	132·1	132·3	132·9	131·6	130·9	131·0	132·1	131·8	132·7
Normal	131·6	130·7	131·5	131·7	131·9	132·1	131·6	129·7	130·2	131·8	131·8	132·4

HORIZONTAL INTENSITY—Continued.

magnetometer of the Los Angeles Magnetic Observatory.

readings referred to standard temperature of magnet. Increasing numbers indicate increasing force.]

JUNE, 1884.

13^h	14^h	15^h	16^h	17^h	18^h	19^h	20^h	21^h	22^h	23^h	Mid-night.	Daily mean.
127	126	125	122	119	122	119*	120*	121	121*	123	124	124·2^{d}
130	127	120*	117*	120	124	125	126	121	120*	124	126	128·3
129	129	125	124	125	126	126	126	127	128	129	130	128·5
136	132	129	127	127	130	131	131	132	133	131	130	131·5
132	133	130	129	126	129	130	131	130	132	129	133	130·0
137	136	136	124	124	127	130	130	131	132	132	130	132·9
133	133	130	128	128	129	130	130	131	132	132	131	130·7
132	132	131	132	132	132	132	133	133	134	134	134	132·4
138	137	133	132	126	130	131	132	134	135	136	137	134·0
135	132	131	132	131	128	129	131	131	132	131	132	132 3
139	135	132	132	132	131	131	132	132	132	133	134	133·5
133	134	132	129	128	127	128	130	129	126	128	129	132·0
134	135	130	123	116*	117*	126	128	128	130	128	130	128·8
134	132	127	125	125	126	128	129	131	132	131	132	130·6
135	134	133	132	130	131	132	133	132	132	133	133	132·9
130	131	132	132	132	133	133	134	133	137	138	139	132·5
135	136	134	134	134	136	138	139*	138	134	138	139	137·1
138	133	135	134	131	117*	124	121	127	130	127	120*	134·2
129	128	128	127	126	128	130	130	132	129	128	126	127·2
132	134	135	134	132	131	130	130	131	131	131	132	130·3
139	140	139	136	134	132	132	134	134	135	136	138	133·9
138	136	133	137	139*	134	132	122	131	136	138	133	134·4
122*	122*	131	126	121	118*	120*	120*	122	117*	121*	126	123·8
126	123*	122*	122	123	124	125	125	126	131	129	128	126·3
126	128	128	128	127	127	127	128	129	130	130	129	128·5
131	132	131	128	126	127	128	129	129	127	128	129	129·5
133	136	136	134	130	129	129	130	130	131	132	134	131·0
132	135	134	131	133	133	132	132	131	131	129	131	133·4
139	134	133	132	130	130	134	132	130	131	129	133	132·8
131	134	129	130	131	128	127	127	128	127	130	128	130·6
132·8	132·3	130·8	129·1	127·9	127·9	129·0	129·2	129·8	130·3	130·6	131·0	130·93
133·2	133·0	131·5	129·5	128·0	129·0	129·6	129·5	129·8	131·5	130·9	131·4	

DIFFERENTIAL MEASURES—

Hourly readings from the photographic traces of the bifilar

[Local mean time. 200 divisions plus tabular quantity, one division=0·000109 in parts of H. All

JULY, 1884.

[For the explanation of these tables see pp. 53, 54.]

Day.	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	Noon.
1	131	128	129	130	130	131	132	130	131	127	126	129
2	129	131	133	134	135	135	131	129	130	[131]	[132]	[133]
3	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
4	[122]	[123]	[123]	[123]	[124]	[124]	[122]	[120]	[120]	[122]	128	126
5	122	122	122	124	125	124	122	118	121	124	124	123
6	124	122	122	123	123	125	125	124	119	121	122	126
7	127	126	126	125	125	123	122	120	126	129	132	133
8	121	119	124	127	129	124	126	121	120	120	124	126
9	128	128	128	129	129	130	126	120	117	119	124	129
10	128	130	127	129	129	128	126	124	122	123	126	130
11	127	131	132	133	131	131	133	129	130	133	132	134
12	127	128	128	129	128	129	127	121	120	122	130	132
13	129	131	132	135	138*	138*	132	128	124	125	133	137
14	121	127	121	124	121	123	122	122	124	124	123	122
15	125	124	125	125	125	127	128	126	128	129	128	129
16	126	132	128	126	126	125	124	119	119	122	126	126
17	127	128	127	127	127	129	129	128	128	128	127	129
18	128	126	126	128	128	128	125	125	125	130	127	124
19	134	133	133	134	134	134	132	131	130	132	132	134
20	123	123	125	123	124	123	120	114*	114*	120	125	128
21	126	127	126	125	126	126	124	122	125	125	123	127
22	126	126	126	127	127	128	125	119	122	124	126	127
23	129	128	128	127	129	128	126	127	132	136*	132	128
24	129	130	130	131	132	131	128	127	130	132	132	133
25	118	130	124	125	129	127	127	126	128	128	126	126
26	124	123	125	122	126	127	126	123	121	118	119	120
27	131	130	130	129	131	130	128	125	126	129	130	128
28	127	126	128	127	128	130	130	128	125	125	128	127
29	129	132	133	133	134	133	132	130	130	130	131	132
30	127	127	126	127	126	127	126	124	124	125	126	125
31	127	127	128	127	128	127	122	122	124	127	130	131
Monthly mean	126·4	127·3	127·2	127·6	128·2	128·2	126·6	124·1	124·5	126·0	127·5	128·5
Normal	126·4	127·3	127·2	127·6	127·9	127·8	126·6	124·4	124·9	125·7	127·5	128·5

HORIZONTAL INTENSITY—Continued.

magnetometer of the Los Angeles Magnetic Observatory.

readings referred to standard temperature of magnet. Increasing numbers indicate increasing force.]

JULY, 1884.

13^h	14^h	15^h	16^h	17^h	18^h	19^h	20^h	21^h	22^h	23^h	Mid-night.	Daily mean.
132	135	129	130	130	129	130	128	130	129	130	129	129·8[d]
[132]	[131]	[130]	[128]	[127]	[128]	[129]	[129]	[130]	[130]	[132]	[132]	[130·9]
. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
123	121	119	118	116	117	122	122	122	119	123	122	121·7
121	117	117	112*	113*	118	119	119	118	119	122	125	120·5
125	125	122	121	117	123	125	126	128	125	128	129	123·8
131	131	127	127	124	121	120	126	126	125	126	123	125·9
126	126	123	123	122	123	124	126	126	126	128	128	124·2
130	128	126	126	127	124	123	126	127	127	128	128	126·1
126	128	120	125	124	126	128	128	129	125	127	128	126·5
134	134	131	129	124	123	126	126	120	120	124	135	129·2
135	129	127	125	125	126	127	126	123	123	126	127	126·7
135	141*	138*	111*	103*	105*	121	123	117	112*	132	120	126·7
121	121	122	118	116	118	120	122	123	124	124	129	122·2
129	129	129	123	123	124	125	114*	120	124	125	126	125·4
122	122	124	119	118	122	125	125	126	127	128	128	124·4
128	126	127	126	127	128	128	128	128	128	127	128	127·6
122	122	121	122	122	126	128	130	129	131	133	133	126·6
137*	134	131	128	121	113*	107*	103*	116	122	121	123	127·0
126	125	124	122	119	122	123	127	127	126	126	126	123·1
128	124	122	122	122	122	124	126	125	127	127	126	124·9
126	127	129	128	129	129	127	126	125	127	128	128	126·3
128	127	127	125	125	126	128	127	129	130	130	130	128·4
132	129	130	129	127	128	129	126	123	118	121	121	128·3
126	125	123	122	117	117	110*	113*	117	122	123	126	123·1
122	125	126	126	126	127	126	132	128	130	130	128	125·0
124	118	122	124	125	124	127	128	128	128	125	124	126·8
124	122	124	125	125	125	125	128	129	129	128	128	126·7
130	128	129	128	125	125	126	126	126	126	126	126	129·2
120	119	124	126	124	123	126	127	127	126	127	129	125·3
130	126	122	121	124	124	126	127	127	129	128	125	126·2
127·5	126·5	125·5	123·6	122·2	122·9	124·1	124·7	125·0	125·1	126·8	127·0	125·96
127·2	126·0	125·1	124·5	123·2	123·9	125·2	126·3	125·0	125·6	126·8	127·0	

DIFFERENTIAL MEASURES—

Hourly readings from the photographic traces of the bifilar

[Local mean time. 200 divisions plus tabular quantity, one division = 0·000109 in parts of H. Al

AUGUST, 1884.

[For the explanation of these tables see pp. 53, 54.]

Day.	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	Noon.
1	126	127	128	128	129	129	126	121	125	125	123	122
2	127	127	127	126	128	129	125	122	123	121	121	124
3	129	127	128	128	129	131	130	130	128	125	123	122
4	127	126	125	127	125	125	123	120	125	131	132*	132*
5	129	128	128	129	128	130	125	121	123	123	126	127
6	130	129	130	130	132	130	126	120	120	121	124	128
7	132	132	131	132	132	132	125	128	129	131	132*	133*
8	130	132	131	131	132	129	130	129	128	124	101*	119
9	127	122	131	128	126	123	121	118	118	116	115	116
10	132	124	125	126	124	124	124	120	122	122	125	123
11	130	126	125	125	126	124	123	119	123	122	122	124
12	127	127	127	128	128	127	128	126	125	124	124	123
13	126	128	128	129	130	125	122	119	126	128	127	123
14	127	128	130	132	129	132	129	124	122	117	118	120
15	126	125	128	126	125	126	124	119	118	119	120	121
16	123	125	124	125	124	124	120	118	125	127	126	123
17	127	126	126	126	126	126	123	121	122	123	124	124
18	128	128	128	129	129	130	123	117	119	122	126	127
19	128	128	128	128	126	127	126	124	123	124	125	124
20	130	130	130	130	129	128	124	128	134*	138*	139*	136*
21	128	126	131	125	123	122	120	122	124	125	120	119
22	124	120	122	124	125	120	123	122	116	110*	114	114
23	119	125	124	122	121	122	120	117	116	116	118	116
24	125	126	125	127	124	124	122	123	123	121	119	120
25	121	122	123	124	125	125	126	124	122	119	120	121
26	127	126	126	127	127	126	122	119	119	121	122	122
27	127	122	123	124	124	124	120	116	116	116	119	121
28	124	124	124	125	126	124	118	114	114	117	118	118
29	124	124	124	124	126	125	121	116	118	121	124	126
30	126	125	124	125	126	126	124	119	117	118	118	120
31	127	127	126	127	128	128	126	122	119	118	119	125
Monthly mean	126·9	126·2	126·8	127·0	126·8	126·4	123·8	121·2	122·0	122·1	122·1	123·0
Normal	126·9	126·2	126·8	127·0	126·8	126·4	123·8	121·2	121·6	122·0	121·5	121·8

HORIZONTAL INTENSITY—Continued.

magnetometer of the Los Angeles Magnetic Observatory.

readings referred to standard temperature of magnet. Increasing numbers indicate increasing force.]

AUGUST, 1884.

13^h	14^h	15^h	16^h	17^h	18^h	19^h	20^h	21^h	22^h	23^h	Mid-night.	Daily mean.
120	117	116	120	121	126	128	126	126	126	128	128	124·6[d]
120	121	126	127	128	129	127	130	129	128	127	128	125·8
124	124	128	126	126	128	128	130	129	129	128	129	127·5
130	132	133*	128	125	127	127	127	127	128	129	129	127·5
125	126	128	127	124	127	126	126	128	130	130	130	126·8
129	129	129	127	129	130	134*	134*	133	132	132	132	128·8
131	127	124	123	125	127	129	130	127	128	121	126	128·6
124	122	120	112*	110*	118	123	122	125	127	128	127	123·9
119	112*	117	116	120	119	117	119	125	127	126	125	121·0
119	122	116	122	122	124	124	122	126	126	125	126	123·5
128	128	131	129	125	124	125	127	126	126	126	126	125·4
124	121	121	119	116	124	124	127	123	130	132	128	125·1
125	127	126	122	124	126	125	125	125	128	128	126	125·8
125	119	124	126	125	125	122	122	126	122	125	125	124·8
121	121	120	120	121	123	123	121	120	123	123	122	122·3
122	120	119	120	121	123	124	124	124	124	125	125	123·1
125	126	127	127	125	125	126	126	125	126	126	131	125·4
128	128	129	126	122	123	124	125	127	126	126	126	125·7
125	126	126	126	125	130	130	128	128	129	130	129	126·8
133*	130	126	117	122	122	124	122	120	112*	122	122	127·0
117	113*	104*	112*	116	120	122	122	120	123	118	112*	120·2
105*	108*	109*	112*	117	119	120	120	118	120	118	119	117·5
117	119	121	122	122	122	120	123	124	124	125	125	120·8
119	117	118	123	121	122	122	121	125	122	121	123	122·2
124	126	128	126	126	125	124	127	126	126	126	126	124·3
124	124	124	123	122	121	120	120	123	123	122	123	123·0
121	120	119	119	120	123	125	125	125	125	125	124	121·8
119	120	121	123	123	126	126	125	126	124	120	121	121·7
128	128	127	127	127	127	126	126	122	122	123	125	124·2
123	127	128	129	129	128	127	126	127	126	128	127	124·7
127	129	126	122	123	125	124	125	126	124	125	126	124·8
123·3	122·9	122·9	122·5	122·6	124·5	124·7	124·9	125·2	125·4	125·4	125·5	124·34
123·6	124·1	123·7	123·6	123·1	124·5	124·4	124·6	125·2	125·8	125·4	126·0	

DIFFERENTIAL MEASURES—

Hourly readings from the photographic traces of the bifilar

[Local mean time. 200 divisions plus tabular quantity, one division = 0·000109 in parts of H. All

SEPTEMBER, 1884.

[For the explanation of these tables see pp. 53, 54.]

Day.	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	Noon.
1	126	124	125	126	125	124	122	120	119	117	121	124
2	126	126	126	127	127	127	122	120	121	125	128*	130*
3	125	124	125	126	125	124	118	119	120	122	123	123
4	124	124	124	124	125	124	118	113	114	115	120	124
5	126	126	127	127	127	125	122	118	119	120	122	127
6	124	126	126	126	125	124	118	114	111	114	113	118
7	127	126	126	127	127	128	126	121	116	114	116	118
8	124	124	124	123	123	122	120	115	109	109	112	117
9	126	125	124	125	125	124	123	120	117	113	114	117
10	120	118	121	120	119	120	117	114	118	117	118	120
11	119	112*	117	117	120	116	120	118	120	122	123	122
12	120	121	122	120	121	122	119	117	117	118	119	119
13	129	119	120	124	126	123	124	122	121	124	122	114
14	104*	108*	126	117	118	119	119	116	117	115	116	112
15	116	118	119	118	119	117	114	111	112	113	114	117
16	121	120	120	120	120	118	113	108	109	112	115	116
17	125	119	124	127	126	123	119	114	112	113	118	113
18	109*	111*	104*	107*	109*	104*	102*	103*	104*	102*	97*	107*
19	111*	113	114	112*	115	114	113	109	107	106*	110	112
20	116	117	118	118	116	116	113	108	104*	104*	105*	109
21	118	118	119	118	119	117	117	110	106*	105*	106*	107*
22	120	116	118	118	119	119	117	113	111	109	108*	110
23	118	119	120	122	122	120	117	111	106*	103*	106*	109
24	120	122	121	122	121	120	117	112	110	110	114	116
25	121	122	123	124	126	124	122	117	116	116	118	119
26	118	119	119	122	120	121	119	117	118	120	119	122
27	122	123	123	124	124	123	122	122	122	123	125	125
28	121	121	120	121	121	122	120	120	122	126	125	123
29	120	120	120	121	122	120	120	120	119	118	118	117
30	126	130	126	128	128	132*	122	125*	127*	127*	126	121
Monthly mean	120·7	120·4	121·4	121·8	122·0	121·1	118·5	115·6	114·8	115·1	116·4	117·6
Normal	122·1	121·5	122·0	122·7	122·4	121·3	119·1	115·7	115·9	116·5	118·4	117·6

HORIZONTAL INTENSITY—Continued.

magnetometer of the Los Angeles Magnetic Observatory.

readings referred to standard temperature of magnet. Increasing numbers indicate increasing force.]

SEPTEMBER, 1884.

13^h	14^h	15^h	16^h	17^h	18^h	19^h	20^h	21^h	22^h	23^h	Mid-night.	Daily mean.
126	128	127	125	124	124	124	124	123	125	126	126	124·0[d]
131*	126	125	127	129	129	124	123	123	127	126	125	125·8
124	122	123	124	124	124	123	125	126	125	125	126	123·5
126	127	125	123	123	123	123	123	125	125	125	126	122·6
130*	131*	130*	130*	127	125	127	129	125	122	124	118	125·2
122	125	124	125	124	124	124	124	124	125	125	128	122·2
120	120	122	123	125	124	124	124	122	122	125	124	122·8
120	123	126	125	124	124	124	124	124	124	124	125	121·2
121	124	126	128	128	126	121	121	121	124	122	116	122·1
121	118	109*	121	116	118	115	115	114	113	123	126	118·0
120	117	116	117	119	120	120	119	119	119	120	124	119·0
118	120	119	120	119	116	117	118	119	118	116	113	118·7
114	114	112	108*	106*	103*	100*	106*	114	104*	105*	101*	114·8
112	109*	104*	104*	104*	108*	112	110*	113	112	111*	115	112·5
116	116	115	114	115	116	118	118	119	119	121	120	116·5
118	120	120	120	119	121	124	124	125	125	127	126	119·2
110	112	106*	89*	100*	92*	73*	80*	97*	90*	87*	89*	106·6
106*	112	108*	108*	106*	108*	110*	112	115	103*	114	115	107·3
114	116	114	113	112	115	114	115	116	115	114	117	113·0
112	112	110*	107*	110*	115	117	117	117	117	117	117	113·0
111	115	116	117	114	112	113	117	116	118	122	119	114·6
111	113	116	116	116	116	117	116	117	117	120	118	115·5
114	119	122	122	121	120	120	120	121	121	121	121	117·3
117	120	121	122	120	120	121	121	121	121	121	120	118·8
119	121	122	122	120	120	120	120	117	118	120	120	120·3
124	124	123	121	120	121	122	121	122	122	121	122	120·7
124	122	120	120	121	123	124	125	124	122	122	122	122·8
119	114	117	116	116	119	120	120	121	121	120	120	120·2
116	116	116	122	122	125	125	126	125	126	126	126	121·1
118	116	116	117	118	121	121	123	120	121	122	123	123·1
118·5	119·1	118·3	118·2	118·1	118·4	117·9	118·7	119·5	118·7	119·7	119·6	118·75
118·0	119·0	120·1	120·8	120·6	120·8	120·5	120·9	120·3	120·9	121·8	121·4	

DIFFERENTIAL MEASURES—

Hourly readings from the photographic traces of the bifilar

[Local mean time. 200 divisions plus tabular quantity, one division = 0·000109 in parts of H. All

OCTOBER, 1884.

[For the explanation of these tables see pp. 53, 54.]

Day.	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	Noon.
1	121	123	122	122	122	121	119	119	121	122*	122*	122*
2	103*	100*	95*	101*	104*	104*	106*	86*	100*	109	111	109
3	104*	106*	107*	109	108*	108*	105*	102*	102*	106	109	110
4	114	112	114	113	114	112	112	106	103*	105	106	106
5	114	121	116	116	116	112	113	110	106	103*	104	106
6	112	113	114	119	117	117	116	114	112	113	111	110
7	112	114	115	116	117	114	111	106	98*	102*	100*	105
8	116	116	117	117	118	116	116	112	108	93*	104	104
9	117	118	119	119	119	118	119	118	115	108	112	109
10	115	116	117	117	115	115	115	113	108	109	109	109
11	118	117	118	118	118	117	116	115	114	114	112	113
12	118	118	119	119	119	119	116	115	115	118	120	122*
13	120	119	118	118	118	117	116	114	113	115	116	118
14	108	106*	115	115	116	117	117	116	113	120	120	115
15	111	119	114	119	117	118	116	111	110	114	114	113
16	113	114	115	115	115	116	114	112	112	112	114	114
17	113	115	119	120	124	117	112	114	110	112	112	113
18	118	118	118	117	118	117	116	114	111	111	110	114
19	121	122	120	120	117	119	119	116	111	108	110	111
20	120	120	120	119	121	120	119	120	118	117	118	117
21	124	121	120	121	120	118	121	118	123*	119	116	116
22	120	119	123	120	121	120	119	116	116	115	115	114
23	119	119	121	120	119	119	118	116	115	114	112	113
24	120	121	122	121	122	121	119	116	114	111	111	114
25	110	113	113	116	116	116	117	116	113	110	109	111
26	116	119	119	119	116	120	116	114	113	110	113	114
27	118	118	120	120	120	120	118	116	115	113	113	113
28	123	120	119	119	120	124	123	121	122	121	120	122*
29	110	114	113	116	116	118	120	121	114	112	112	113
30	113	114	114	115	115	116	115	113	110	110	109	108
31	118	117	118	118	117	117	118	116	114	111	110	112
Monthly mean	115·4	116·2	116·6	117·2	117·3	116·9	116·0	113·4	111·9	111·5	112·1	112·6
Normal	116·3	117·5	117·6	117·8	118·0	117·6	116·8	114·8	113·2	112·5	112·1	111·6

HORIZONTAL INTENSITY—Continued.

magnetometer of the Los Angeles Magnetic Observatory.

readings referred to standard temperature of magnet. Increasing numbers indicate increasing force.]

OCTOBER, 1884.

13^h	14^h	15^h	16^h	17^h	18^h	19^h	20^h	21^h	22^h	23^h	Mid-night.	Daily mean.
121	121	130*	127*	124	126*	84*	80*	78*	91*	91*	90*	113·3[d]
104*	96*	88*	88*	83*	82*	78*	88*	94*	104*	109	105*	97·8
112	110	110	109	109	107	108	111	112	111	112	114	108·4
108	110	107	105*	105*	106	111	112	114	113	113	113	109·8
113	115	117	118	116	115	113	106	110	110	111	111	112·2
110	110	113	109	108	107	103*	101*	102*	104*	103*	110	110·3
104*	106	110	111	113	111	114	113	115	115	115	115	110·5
110	113	116	115	116	116	114	114	115	114	117	117	113·1
112	115	115	116	117	119	117	111	108	111	112	114	114·9
112	113	115	115	114	115	113	113	115	115	116	116	113·8
114	115	116	118	118	118	118	118	118	118	118	117	116·5
123*	122	121	118	117	118	120	119	119	118	118	119	118·8
119	118	118	119	115	112	116	117	118	117	109	106*	116·1
114	115	111	108	104*	104*	104*	106	109	112	112	113	112·1
109	109	105*	107	108	109	113	110	112	111	110	115	112·2
114	113	112	113	115	117	117	117	117	116	117	121	114·8
116	117	117	118	118	117	116	118	117	117	118	118	116·2
118	120	120	120	119	116	118	117	116	118	116	121	116·7
114	117	117	118	119	120	119	120	120	120	121	120	117·5
117	120	122	119	119	118	118	118	118	117	117	121	118·9
116	116	117	118	118	117	118	118	118	119	120	120	118·8
115	116	117	119	120	120	119	119	119	119	119	120	118·3
113	114	116	117	117	118	119	119	119	119	119	120	117·3
116	117	119	118	117	118	117	112	105*	102*	106	105*	115·2
114	114	113	110	108	109	111	112	113	114	115	115	112·8
107	114	115	114	113	114	115	114	115	115	114	115	114·8
113	116	118	120	120	120	121	118	116	116	116	118	117·3
119	119	118	116	113	112	114	112	114	112	109	110	117·6
113	107	107	109	108	110	111	111	110	109	115	112	112·5
109	110	112	114	116	117	118	117	113	115	113	116	113·4
114	115	117	119	120	120	120	119	121	119	119	120	117·0
113·3	114·0	114·5	114·4	113·8	113·8	112·8	112·3	112·6	113·3	113·5	114·4	114·15
113·6	146·6	115·2	115·2	115·5	114·9	115·9	114·7	115·2	115·2	114·7	116·3	

DIFFERENTIAL MEASURES—

Hourly readings from the photographic traces of the bifilar

[Local mean time. 200 divisions plus tabular quantity, one division = 0·000109 in parts of H. All

NOVEMBER, 1884.

[For the explanation of these tables see pp. 53, 54.]

Day.	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	Noon.
1	120	119	121	123	122	124	122	122	111	123*	118	118
2	114	114	115	111	108	113	116	118	108	104	89*	79*
3	84*	96*	109	116	99*	117	106*	106*	109	107	108	105
4	108	116	108	108	108	108*	109	108	107	105	105	108
5	111	111	113	111	112	111	112	110	107	104	103	104
6	114	114	114	114	113	114	113	112	111	111	109	108
7	117	115	116	116	118	116	116	114	114	109	108	109
8	117	116	116	116	115	118	120	122	118	111	109	109
9	117	115	119	115	116	118	118	115	114	113	111	115
10	115	115	116	116	116	117	115	114	112	112	108	110
11	110	112	115	122	120	114	118	113	110	108	107	107
12	115	116	114	115	116	116	116	117	115	112	108	109
13	117	119	120	119	120	120	121	118	117	116	114	116
14	117	118	118	120	117	119	120	121	116	114	113	104
15	118	119	118	118	119	119	118	116	114	111	111	110
16	119	120	122	123	122	124	123	120	116	113	113	114
17	120	122	122	121	122	122	118	117	112	113	110	109
18	122	117	116	116	115	115	116	116	116	114	109	109
19	118	118	118	117	120	121	119	120	115	114	111	109
20	118	119	120	118	117	120	120	119	121	116	113	113
21	117	122	118	118	118	120	119	117	115	110	109	109
22	118	118	119	119	119	121	121	120	120	115	114	114
23	119	117	119	119	120	121	123	124	124*	114	113	115
24	116	116	116	116	116	118	118	113	115	116	111	113
25	110	112	114	115	116	117	117	120	118	115	112	108
26	114	115	114	115	116	117	117	117	115	113	110	110
27	117	117	117	118	118	118	118	119	117	111	106	106
28	102*	102*	109	112	117	114	109	110	108	105	101	100
29	114	110	111	113	114	114	116	113	115	110	107	106
30	108	110	112	117	115	116	118	117	116	115	112	108
Monthly mean	114·2	115·0	116·0	116·6	116·1	117·4	117·1	116·3	114·2	111·8	109·1	108·5
Normal	115·7	116·1	116·0	116·6	116·7	117·7	117·4	116·6	113·9	111·4	109·8	109·5

HORIZONTAL INTENSITY—Continued.

magnetometer of the Los Angeles Magnetic Observatory.

readings referred to standard temperature of magnet. Increasing numbers indicate increasing force.]

NOVEMBER, 1884.

13^h	14^h	15^h	16^h	17^h	18^h	19^h	20^h	21^h	22^h	23^h	Mid-night.	Daily mean.
117	114	120	118	116	123	113	115	110	108	103*	110	117·1[d]
69*	73*	75*	74*	70*	77*	80*	75*	72*	74*	80*	77*	91·0
106	105	102*	98*	89*	95*	96*	101*	100*	100*	105*	103*	102·6
109	108	113	113	111	111	109	109	112	112	110	111	109·4
106	107	108	109	112	113	114	113	114	114	115	115	110·4
109	109	108	116	112	115	116	116	116	115	115	116	112·9
110	111	114	115	117	117	116	115	114	114	116	116	114·3
111	112	110	114	116	114	105*	111	111	109	110	115	113·5
115	114	114	112	111	104*	108	109	110	112	113	111	113·3
109	109	106	108	114	122	113	112	110	111	109	112	112·5
109	109	113	114	115	116	117	116	116	116	115	115	113·6
110	114	115	116	116	113	114	114	115	114	116	116	114·3
116	116	117	117	117	117	117	118	118	118	121	118	117·8
114	114	114	115	116	116	117	117	118	118	118	118	116·3
111	114	117	119	118	119	119	120	119	119	119	120	116·9
115	116	118	120	120	122	123	123	121	122	123	123	119·8
109	108	110	111	113	113	113	112	113	113	113	112	114·5
109	111	112	111	114	113	114	116	114	116	119	118	114·5
105	108	112	110	115	117	117	117	117	117	117	117	115·4
114	115	117	120	120	119	118	117	118	117	117	118	117·7
111	114	117	118	117	116	117	119	119	118	116	116	116·3
116	118	120	121	122	122	122	122	120	120	116	118	119·0
114	115	109	112	115	116	112	112	109	112	112	115	115·9
111	111	112	114	113	116	117	116	116	113	112	114	114·5
109	111	114	114	115	116	116	115	114	114	114	114	114·2
112	114	115	116	117	118	118	118	118	117	117	117	115·4
109	115	116	117	113	111	110	107	103*	97*	97*	96*	111·4
101*	106	109	111	111	111	112	113	114	111	108	109	108·6
107	109	107	111	112	113	112	112	112	111	112	108	111·2
115	118	116	116	115	114	114	114	113	114	112	119	114·3
109·3	110·6	111·7	112·7	112·7	113·6	113·0	113·1	112·5	112·2	112·3	112·9	113·29
111·0	111·9	113·3	114·6	115·1	116·0	115·1	114·9	114·8	114·6	114.8	115·2	

DIFFERENTIAL MEASURES—

Hourly readings from the photographic traces of the bifilar

[Local mean time. 200 divisions plus tabular quantity, one division = 0·000109 in parts of H. All

DECEMBER, 1884.

[For the explanation of these tables see pp. 53, 54.]

Day.	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	Noon.
1	114	114	115	115	117	114	118	116	113	111	109	108
2	113	114	114	115	116	116	116	115	113	112	108	110
3	113	114	116	115	115	115	116	116	116	116	114	113
4	116	116	117	117	117	117	117	116	116	114	110	110
5	117	116	115	116	116	117	117	117	117	113	110	111
6	116	117	118	118	119	119	120	121	120	115	111	110
7	116	116	117	118	119	119	120	121	120	117	114	113
8	115	113	115	116	116	115	112	116	114	111	105	103
9	113	112	114	115	115	118	118	118	116	111	108	108
10	114	114	116	117	118	118	118	116	114	115	112	110
11	109	110	115	115	116	117	119	121	118	112	104	110
12	112	112	112	114	116	116	118	118	114	111	109	110
13	115	116	116	115	116	117	116	116	115	111	110	113
14	116	112	114	114	114	113	116	114	116	112	109	114
15	96*	99*	98*	109	104*	106*	107*	109	116	112	112	108
16	104	107	106	108	112	111	110	113	110	107	104	104
17	110	112	111	111	111	112	113	112	112	106	102	102
18	112	111	112	114	113	113	112	113	111	111	107	107
19	112	112	113	114	114	115	115	116	116	115	113	124*
20	107	108	114	114	114	112	113	111	110	106	99*	100
21	113	114	114	114	119	114	115	114	113	110	108	106
22	114	115	114	115	116	117	117	117	114	112	108	104
23	105	109	111	115	116	118	122	122	118	115	108	105
24	112	114	114	115	116	116	117	116	116	111	106	105
25	113	113	114	114	115	118	121	122	121	118	112	108
26	116	116	116	116	117	118	120	118	116	111	106	107
27	116	116	117	118	118	121	121	120	117	115	112	112
28	110	112	113	114	115	117	120	117	114	118	114	112
29	114	114	114	113	116	116	116	114	113	107	106	105
30	116	116	116	117	116	116	116	117	116	112	107	110
31	112	115	116	116	116	116	117	116	113	110	107	109
Monthly mean	112·3	112·9	113·8	114·7	115·4	115·7	116·5	116·4	115·1	112·2	108·5	108·7
Normal	112·8	113·3	114.3	114·7	115·8	116·0	116·9	116·4	115·1	112·2	108·8	108·2

HORIZONTAL INTENSITY—Continued.

magnetometer of the Los Angeles Magnetic Observatory.

readings referred to standard temperature of magnet. Increasing numbers indicate increasing force]

DECEMBER, 1884.

13^h	14^h	15^h	16^h	17^h	18^h	19^h	20^h	21^h	22^h	23^h	Mid-night.	Daily mean.
110	112	113	115	114	114	114	115	115	114	113	112	113·5[d]
110	111	113	116	115	114	112	111	113	114	114	114	113·3
111	110	111	114	117	116	116	115	115	115	115	116	114·6
112	110	113	116	117	116	115	114	114	113	113	113	114·5
113	115	116	117	117	115	115	115	115	115	115	116	115·3
113	113	117	118	118	117	117	115	116	116	115	116	116·5
114	116	119	118	118	118	116	115	115	114	111	111	116·5
102	104	107	107	108	108	110	111	110	114	112	111	110·6
110	112	114	114	114	113	114	113	114	114	113	113	113·5
112	113	114	115	115	118	114	108	102*	103*	107	108	113·0
106	105	106	111	112	113	112	111	108	108	107	110	111·5
112	116	117	117	117	118	117	116	116	116	115	115	114·7
116	115	115	116	116	116	117	116	117	115	114	116	115·2
106	101*	108	105	102*	97*	91*	87*	92*	96*	97*	92*	105·7
106	111	106	105	101*	99*	102*	104	102*	115	101*	104	105·5
106	107	107	109	111	110	110	109	106	110	111	110	108·4
105	109	112	111	110	110	111	111	111	110	110	111	109·8
109	112	112	113	113	113	113	112	112	112	112	112	111·7
120*	123*	125*	125*	121	116	109	107	111	107	100*	108	114·6
101	108	107	110	113	114	112	112	112	113	113	112	109·8
108	110	112	108	112	113	114	114	114	114	114	115	112·6
103	103	102	110	114	116	112	107	109	105	104	108	110·7
104	106	112	113	112	112	114	114	114	114	114	113	112·8
106	108	110	108	108	111	112	112	113	111	112	113	111·7
110	114	116	118	115	115	112	112	111	112	114	115	114·7
110	114	117	118	118	118	118	116	115	114	114	114	115·1
113	115	115	120	120	118	113	102*	100*	104	109	111	114·3
112	114	112	109	111	114	114	114	114	114	113	113	113·8
106	107	113	117	117	117	116	116	116	116	107	116	113·4
111	112	114	114	114	111	111	111	111	111	112	116	113·5
111	114	114	116	116	117	117	116	116	115	116	115	114·4
109·3	111·0	112·5	113·6	113·7	113·5	112·6	111·3	111·3	117·7	111·2	111·9	112·74
108·9	110·9	112·1	113·3	114·6	114·5	113·7	112·5	113·1	112·6	112·5	112·6	

DIFFERENTIAL MEASURES—

Hourly readings from the photographic traces of the bifilar

[Local mean time. 200 divisions plus tabular quantity, one division = 0·000109 in parts of H. All

JANUARY, 1885.

[For the explanation of these tables see pp. 53, 54.]

Day.	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	Noon.
1	115	115	116	117	117	117	118	120	119	118	117	117
2	113	116	126*	114	126*	115	109	109	104*	103*	97*	96*
3	109	110	111	112	113	112	113	114	113	112	110	112
4	113	114	113	115	115	114	114	112	110	104	104	103
5	113	115	115	115	116	114	116	116	114	115	114	115
6	115	115	115	116	119	120	120	119	116	108	105	106
7	114	115	115	116	118	118	118	117	115	109	106	106
8	114	115	118	117	117	118	119	119	117	110	104	107
9	109	111	111	114	117	118	116	119	117	115	110	106
10	112	117	116	114	112	114	114	116	116	110	107	107
11	112	114	114	115	116	117	118	117	117	110	108	108
12	115	115	115	118	117	116	118	119	116	115	110	109
13	114	116	116	117	116	118	117	118	118	114	111	111
14	115	116	116	116	117	117	119	120	120	117	114	111
15	115	117	117	117	117	117	118	118	118	113	109	112
16	113	110	114	114	116	117	119	121	119	116	112	110
17	114	115	114	115	116	118	122	123	121	116	112	109
18	112	113	114	115	116	118	118	119	119	114	112	109
19	114	117	113	113	117	115	116	117	113	110	106	108
20	114	113	114	113	115	116	116	115	115	112	107	106
21	114	114	116	116	116	117	118	119	117	112	103	105
22	110	110	115	116	116	117	119	113	103*	99*	101	85*
23	103*	102*	106	107	106*	106*	108	111	110	106	103	103
24	109	109	109	111	110	110	111	108	105*	100*	96*	95*
25	108	109	109	110	111	113	112	115	116	113	111	113
26	113	114	113	112	113	113	114	113	111	110	107	108
27	116	116	116	115	115	117	117	118	120	117	115	111
28	113	113	113	114	114	115	114	116	114	111	107	109
29	113	112	112	113	115	115	114	116	116	113	111	112
30	98*	98*	104*	110	108	114	109	110	106*	102*	101	99*
31	110	110	111	111	111	111	113	115	116	116	115	115
Monthly mean	112·0	112·8	113·8	114·1	115·1	115·4	115·8	116·2	114·5	111·0	107·9	107·2
Normal	112·8	113·7	113·7	114·1	115·0	115·7	115·8	116·2	116·0	112·4	108·7	109·2

HORIZONTAL INTENSITY—Continued.

magnetometer of the Los Angeles Magnetic Observatory.

readings referred to standard temperature of magnet. Increasing numbers indicate increasing force.]

JANUARY, 1885.

13^h	14^h	15^h	16^h	17^h	18^h	19^h	20^h	21^h	22^h	23^h	Mid-night.	Daily mean.
117	119	120	120	118	118	118	118	113	108	106	107	116·2d
102	105	104	99*	102*	100*	97*	101*	108	108	108	108	107·0
113	114	113	111	110	112	111	110	111	112	114	113	111·9
104	107	112	113	113	114	114	114	112	112	115	114	111·4
115	114	116	116	116	116	116	116	113	113	114	115	114·9
111	115	115	118	117	115	116	114	115	113	114	114	114·6
109	111	113	113	114	115	117	116	115	114	114	114	113·8
109	112	110	107	99*	100*	94*	97*	101*	104	106	107	109·2
110	112	113	112	111	114	112	109	110	108	108	113	112·3
108	109	110	111	109	110	111	115	112	113	115	113	112·1
111	112	112	112	115	113	112	114	114	114	115	115	113·5
108	110	112	112	115	116	113	114	114	115	114	116	114·3
111	114	116	116	116	119	116	116	115	116	115	116	115·5
111	110	111	115	116	117	117	117	116	116	116	116	115·7
113	116	117	118	117	115	116	115	117	117	116	112	115·7
108	110	114	114	116	116	116	115	116	113	114	115	114·5
114	119	119	119	115	116	111	101*	110	112	113	112	114·8
107	108	105	109	111	113	113	114	112	113	113	114	113·0
111	110	111	112	113	112	111	112	112	113	113	113	112·6
105	105	109	112	112	116	117	115	113	113	114	114	112·5
108	112	111	112	111	113	112	114	115	114	113	109	113·0
81*	84*	94*	93*	92*	98*	103*	105	107	106	102*	107	103·2
104	106	107	109	108	107	110	110	108	109	108	109	106·9
101	104	105	108	109	110	112	109	112	108	109	108	107·0
113	111	110	110	109	110	112	111	111	112	112	113	111·4
110	112	114	113	114	116	117	117	117	118	116	116	113·4
110	110	110	109	109	108	112	112	113	112	112	112	113·4
110	109	109	109	109	106	108	113	115	115	114	114	111·8
107	110	113	108	107	113	112	108	108	107	114	95*	111·0
101	103	106	107	108	108	108	109	109	110	110	111	106·2
114	111	108	108	111	113	113	113	113	112	112	112	112·2
108·3	109·8	110·9	111·1	111·0	111·9	111·8	111·7	112·2	112·0	112·2	111·8	112·10
109·2	110·7	111·5	112·1	112·5	113·2	113·3	113·0	112·5	112·0	112·6	112·4	

DIFFERENTIAL MEASURES—

Hourly readings from the photographic traces of the bifilar

[Local mean time. 200 divisions plus tabular quantity, one division = 0·000109 in parts of H. All

FEBRUARY, 1885.

[For the explanation of these tables see pp. 53, 54.]

Day.	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	Noon.
1	113	113	112	113	113	113	113	114	114	113	114	115
2	110	111	111	111	111	112	112	112	111	110	108	110
3	110	111	111	116	113	112	112	109	107	105	105	108
4	113	113	114	114	115	114	114	110	108	102	105	107
5	116	115	115	116	118	121	119	114	102	101*	103	95*
6	110	108	108	109	110	111	109	109	106	108	106	107
7	112	112	114	115	115	115	116	117	116	114	111	108
8	112	112	112	117	113	112	112	115	106	113	110	110
9	111	111	110	112	113	112	115	114	115	112	110	107
10	114	114	123*	113	109	106	110	108	107	108	105	98*
11	109	110	110	110	111	112	111	110	110	110	111	111
12	105	100*	102*	105	110	110	110	111	103	111	114	106
13	110	106	107	107	107	109	109	109	108	112	109	109
14	108	108	109	108	107	108	109	108	107	106	107	108
15	111	111	111	111	111	111	110	108	107	107	107	106
16	112	111	112	113	113	113	111	110	107	106	104	103
17	110	111	118	114	112	114	111	110	108	107	108	109
18	106	109	112	113	111	113	109	111	110	108	104	106
19	112	112	112	115	113	113	112	112	112	111	111	109
20	115	115	115	116	115	116	116	116	114	112	107	106
21	115	115	114	114	114	114	112	113	112	115	112	110
22	104	112	109	110	110	110	100	108	109	114	113	105
23	[113]	[114]	[115]	[116]	[116]	[116]	[116]	116	115	114	112	112
24	114	114	115	115	115	116	117	115	115	116	113	114
25	[114]	[115]	[115]	[115]	[115]	[116]	[114]	114	113	114	[112]	115
26	116	116	115	116	116	115	116	116	115	115	115	115
27	101*	107	108	110	120	119	109	113	113	111	108	103
28	113	114	115	114	118	118	120	118	112	112	112	106
Monthly mean	111·0	111·4	112·3	112·8	113·0	113·2	112·3	112·1	110·1	110·2	109·1	107·8
Normal	111·4	111·9	112·3	112·8	113·0	113·2	112·7	112·1	110·1	110·6	109·1	108·7

HORIZONTAL INTENSITY—Continued.

magnetometer of the Los Angeles Magnetic Observatory.

readings referred to standard temperature of magnet. Increasing numbers indicate increasing force.]

FEBRUARY, 1885.

13^h	14^h	15^h	16^h	17^h	18^h	19^h	20^h	21^h	22^h	23^h	Mid-night.	Daily mean.
116	115	114	114	113	109	106	104	104	102	107	108	111.3^d
114	117	118	115	113	112	111	110	108	108	111	111	111·5
112	115	116	116	114	114	114	112	112	112	112	112	111·7
110	112	113	116	114	116	117	116	117	117	117	117	113·0
96*	96*	95*	99*	104	96*	97*	101*	102	100*	103	104	105·3
105	103	108	108	109	112	109	113	112	111	112	112	109·0
106	108	107	108	108	112	112	111	111	110	109	112	111·6
108	107	108	107	110	112	112	110	107	107	109	111	110·5
106	105	107	107	108	111	111	112	116	113	113	114	111·0
98*	101	102	105	105	104	106	110	110	108	108	107	107·5
110	111	110	109	109	110	117	90*	87*	88*	98*	99*	106·8
112	103	100*	99*	96*	104	107	110	114	112	108	108	106·7
107	104	105	104	104	106	107	105	108	107	108	108	107·3
108	109	110	110	109	110	110	112	112	110	110	111	108·9
108	110	113	112	109	110	113	113	114	113	113	111	110·4
104	104	106	109	110	111	111	110	109	109	109	109	109·0
108	111	112	99*	105	106	108	109	110	110	114	114	109·9
110	112	108	106	111	110	111	110	110	109	113	112	109·8
107	107	109	112	112	113	114	114	114	114	114	115	112·0
108	111	114	116	116	115	111	112	117	116	117	112	113·7
110	109	108	108	113	98*	105	106	106	102	104	104	109·7
110	109	109	110	112	113	112	[111]	[112]	[112]	[112]	[113]	[100·0
112	111	112	113	114	114	114	115	115	114	114	114	[114·0
115	114	[114]	[112]	112	113	114	115	115	[114]	[114]	[114]	[114·4]
112	112	113	113	114	114	116	116	116	115	115	116	[114·3]
114	113	115	117	118	117	114	108	108	124*	105	110	114·5
101	103	107	112	113	116	111	113	114	114	117	110	110·5
102	105	103	101*	98*	94*	103	101*	105	108	105	112	108·7
108·2	108·5	109·3	109·2	109·8	109·7	110·5	109·6	110·2	110·0	110·4	110·7	110·47
109·0	108·9	110·2	110·8	110·7	111·4	111·0	111·1	111·0	110·7	110·9	111·1	

DIFFERENTIAL MEASURES—

Hourly readings from the photographic traces of the bifilar

[Local mean time. 200 divisions plus tabular quantity, one division = 0·000109 in parts of H. All

MARCH, 1885.

[For the explanation of these tables see pp 53, 54.]

Day.	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	Noon.
1	122*	106	105	109	111	111	110	108	107	106	106	107
2	106	109	108	108	108	108	108	110	112	112	112	107
3	111	108	111	112	111	111	111	108	108	102	107	107
4	112	112	112	112	113	112	112	112	111	111	111	108
5	113	112	113	114	114	114	114	112	112	111	107	104
6	114	114	114	114	115	116	115	114	115	114	112	110
7	114	114	115	118	116	117	116	115	113	111	109	105
8	112	111	114	113	114	113	112	111	110	109	105	102
9	112	113	113	114	115	115	114	113	111	110	109	108
10	115	114	114	115	116	118	118	116	115	114	111	112
11	116	117	118	118	118	118	117	115	113	111	108	109
12	108	109	112	111	112	111	111	107	106	107	105	104
13	112	111	114	114	114	118	119	124*	114	108	109	104
14	109	111	111	112	111	113	113	111	112	118	116	112
15	112	113	96*	120	113	98*	101*	85*	82*	80*	70*	66*
16	87*	92*	93*	94*	96*	95*	97*	99*	98*	98*	97*	96*
17	104	104	105	106	106	106	105	102*	100*	103	102	100
18	109	110	110	110	108	108	109	109	109	110	106	104
19	111	112	111	111	111	111	112	109	107	106	106	106
20	108	108	111	115	111	113	114	113	110	106	100	103
21	105	107	110	109	109	109	108	107	107	109	107	104
22	107	108	115	111	110	111	112	110	109	108	104	104
23	112	113	116	115	114	113	114	110	110	115	114	112
24	112	112	112	113	114	113	113	112	111	112	109	104
25	112	112	113	113	115	114	114	112	111	111	109	105
26	113	114	114	114	115	116	117	116	116	115	112	110
27	114	115	116	116	115	116	115	112	112	113	113	110
28	115	113	116	116	117	118	118	114	111	111	109	107
29	115	116	115	115	115	116	116	114	114	113	109	107
30	114	115	115	115	116	116	116	112	111	110	110	110
31	114	113	114	114	113	113	115	114	112	111	111	112
Monthly mean	111·0	110·9	111·5	112·6	112·5	112·3	112·5	110·5	109·3	108·9	106·9	105·1
Normal	111·4	111·5	112·7	113·2	113·0	113·4	113·4	111·7	111·0	110·2	108·6	106·8

HORIZONTAL INTENSITY—Continued.

magnetometer of the Los Angeles Magnetic Observatory.

readings referred to standard temperature of magnet. Increasing numbers indicate increasing force.]

MARCH, 1885.

13h	14h	15h	16h	17h	18h	19h	20h	21h	22h	23h	Mid-night.	Daily mean.
106	104	105	100*	102*	102*	106	110	106	106	104	104	106·8d
106	109	110	110	110	110	111	110	112	108	110	110	109·3
105	108	106	109	112	112	111	105	107	110	110	110	108·8
107	108	111	112	110	111	113	112	112	111	112	113	111·2
104	106	111	111	112	113	111	109	110	112	113	114	111·1
114	116	116	115	114	115	116	114	111	113	114	114	114·1
103	106	108	110	112	114	115	114	114	111	112	111	112·2
104	109	112	113	113	114	113	113	114	112	112	112	111·1
109	111	112	113	113	115	115	116	116	115	115	114	113·0
113	115	117	117	115	116	116	116	116	116	116	116	115·3
112	116	117	117	117	117	117	116	116	115	110	108	114·8
104	107	107	109	109	111	112	113	114	114	114	114	109·6
96*	102	110	110	109	111	107	106	106	107	111	108	110·2
110	110	110	109	108	108	110	110	107	104	93*	122*	110·4
71*	68*	76*	77*	74*	74*	65*	76*	68*	85*	84*	86*	85·0
96*	94*	94*	95*	95*	97*	99*	98*	99*	102	100*	106	96·5
100	102	103	104	104	104	106	106	106	107	106	106	104·2
105	108	109	110	110	109	110	110	109	109	110	110	108·8
106	110	114	116	113	110	111	112	111	110	110	108	110·2
100	94*	101*	108	102*	96*	93*	97*	99*	99*	100*	103	104·5
103	101	101*	106	106	106	106	106	106	106	107	107	106·3
106	110	114	113	113	113	113	112	113	113	112	113	110·6
112	112	111	113	112	112	112	112	111	110	111	112	112·4
106	103	109	111	112	110	112	112	112	113	113	112	110·9
103	105	108	111	113	113	113	113	114	114	114	114	111·5
110	112	113	114	112	114	113	114	114	114	113	115	113·8
107	108	110	112	114	115	115	115	115	115	115	116	113·5
107	106	108	110	112	113	115	114	115	114	115	115	112·9
109	110	113	112	113	114	115	115	115	114	114	114	113·5
112	115	117	116	114	113	111	113	114	114	114	114	113·6
113	114	116	117	115	111	112	115	111	106	111	106	112·6
105·1	106·4	108·7	109·7	109·4	109·5	109·5	109·8	109·5	109·6	109·5	110·6	109·64
107·0	108·7	111·0	111·7	111·8	112·0	112·0	111·9	111·7	110·9	111·8	111·0	

DIFFERENTIAL MEASURES—

Hourly readings from the photographic traces of the bifilar

[Local mean time. 200 divisions plus tabular quantity, one division = 0·000109 in parts of H. All

APRIL, 1885.

[For the explanation of these tables see pp. 53, 54.]

Day.	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	Noon.
1	106	111	111	116	113	114	115	113	112	113	115	116
2	113	113	114	112	112	114	113	112	113	113	110	109
3	114	112	117	113	115	110	113	104	104	100	101	105
4	113	114	114	115	114	111	110	109	107	104	104	106
5	114	114	113	114	114	114	113	110	109	107	107	109
6	114	116	116	117	117	117	115	114	109	104	103	104
7	113	112	112	112	113	113	111	109	109	108	107	105
8	100*	107	106	106	110	111	109	111	109	102	105	105
9	108	108	111	110	109	110	107	106	105	105	109	110
10	113	113	114	112	115	115	114	112	111	112	112	110
11	114	114	115	115	118	116	116	111	109	106	107	107
12	108	111	111	114	116	117	115	111	109	108	110	109
13	98*	101*	105	104	109	109	109	110	114	114	118	117
14	113	114	114	114	113	114	113	111	109	110	110	110
15	105	108	111	110	111	111	108	107	97*	108	104	107
16	112	110	115	114	112	112	104	100*	99*	101	104	105
17	110	111	112	112	113	113	112	113	113	113	111	110
18	117	113	115	114	117	115	115	114	114	110	110	110
19	118	117	117	116	116	118	118	119	109	104	106	109
20	114	113	114	117	118	119	116	112	108	107	108	110
21	114	116	115	112	114	115	114	114	112	110	110	114
22	113	114	113	115	116	117	117	116	114	112	113	115
23	114	114	114	114	114	114	114	112	115	117	119*	121*
24	112	112	113	114	114	115	112	110	106	111	112	111
25	114	113	112	112	113	113	111	108	108	109	109	110
26	114	116	114	114	115	114	114	113	111	111	111	108
27	97*	102*	105	110	110	110	111	108	109	108	108	110
28	110	104	108	101*	114	108	106	101*	99*	103	111	109
29	110	110	112	110	110	109	107	103	101	105	108	109
30	113	113	114	114	112	112	109	106	106	108	109	110
Monthly mean	110·9	111·5	112·6	112·4	113·6	113·3	112·0	110·0	108·3	108·1	109·0	109·7
Normal	112·3	112·2	112·6	112·8	113·6	113·3	112·0	110·6	109·4	108·1	108·7	109·3

HORIZONTAL INTENSITY—Continued.

magnetometer of the Los Angeles Magnetic Observatory.

readings referred to standard temperature of magnet. Increasing numbers indicate increasing force.]

APRIL, 1885.

13h	14h	15h	16h	17h	18h	19h	20h	21h	22h	23h	Mid-night.	Daily mean.
113	115	113	112	111	112	112	111	111	110	113	115	112·6d
109	111	110	111	110	109	107	108	109	111	112	115	111·2
108	108	107	108	109	111	110	111	109	112	111	113	109·4
107	107	110	112	112	111	113	113	112	113	113	113	110·7
110	112	113	115	115	115	114	114	115	115	114	114	112·7
106	111	112	113	114	113	113	116	109	110	110	109	111·8
108	107	109	114	114	112	110	95*	100*	97*	96*	94*	107·5
103	103	104	101*	108	108	109	108	109	108	106	111	106·6
110	110	110	114	115	113	114	113	112	113	112	113	110·3
109	112	114	114	110	113	112	112	111	111	113	114	112·4
111	113	118	116	115	114	113	113	114	114	112	109	112·9
112	111	110	106	103*	106	108	108	104	99*	95*	96*	108·2
116	116	116	116	116	112	110	111	114	115	114	114	111·6
112	111	109	110	108	107	106	100*	96*	97*	102*	105	108·7
107	104	111	107	110	112	112	112	112	113	114	112	108·9
108	107	109	110	110	112	112	112	109	102*	105	110	108·1
110	111	113	114	114	113	112	112	113	114	114	112	112·3
112	106	107	113	113	113	112	112	120	118	116	118	113·5
111	108	110	112	112	110	108	109	107	109	112	114	112·0
114	111	108	111	113	110	108	110	110	113	112	113	112·0
114	113	114	114	113	112	112	113	113	112	113	113	113·2
116	114	114	113	113	113	113	111	110	111	112	113	113·7
124*	126*	124*	122*	119	117	117	117	116	114	112	108	116·6
113	112	111	112	113	112	109	110	110	112	112	113	111·7
111	114	113	114	114	113	112	114	113	114	113	114	112·1
111	113	112	111	110	102*	101*	98*	81*	92*	94*	92*	107·2
112	110	109	107	120	116	110	102	116	105	110	109	108·9
110	108	107	108	105	105	106	106	107	108	108	109	106·7
112	114	114	113	112	110	111	111	110	112	111	112	109·8
110	112	115	115	113	111	109	107	110	112	113	113	111·1
111·0	111·0	111·5	111·9	112·1	111·2	110·5	109·6	109·4	109·5	109·8	110·3	110·81
110·5	110·5	111·1	112·0	112·4	111·6	110·8	111·0	111·3	112·0	111·8	112·1	

DIFFERENTIAL MEASURES—

Hourly readings from the photographic traces of the bifilar

[Local mean time. 200 divisions plus tabular quantity, one division = 0·000109 in parts of H. All

MAY, 1885.

[For the explanation of these tables see pp. 53, 54.]

Day.	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	Noon.
1	114	114	115	115	115	113	112	109	108	110	111	112
2	111	113	114	113	113	113	110	110	112	115	114	113
3	115	116	114	115	115	114	114	113	114	112	110	109
4	115	118	118	116	117	117	114	109	111	113	114	118
5	114	114	114	113	115	114	113	109	111	112	113	114
6	114	114	114	113	112	112	113	112	113	111	114	115
7	111	112	116	112	112	114	110	113	114	115	115	115
8	111	111	110	110	112	111	109	109	112	114	115	116
9	117	118	116	118	117	116	114	115	117	119	119	120
10	123*	121	120	126*	131*	113	111	115	113	110	107	109
11	100*	104	104	109	108	113	111	108	103	102	106	104
12	115	106	111	110	112	110	107	107	107	108	110	111
13	116	116	116	115	114	113	113	109	100*	90*	85*	89*
14	102*	103*	102*	103	103	102*	101*	100*	100*	98*	99*	100*
15	105	108	108	108	109	108	108	106	106	105	102*	98*
16	111	111	114	107	108	108	108	107	106	109	112	112
17	112	113	113	113	113	114	113	115	116	113	109	110
18	111	113	114	114	116	114	111	112	115	115	115	114
19	112	112	112	113	114	114	116	116	115	112	113	110
20	112	114	115	114	115	116	117	117	122*	123*	124*	122*
21	110	110	111	112	113	114	112	114	113	115	112	111
22	113	114	114	114	115	115	115	113	110	114	114	113
23	120	120	118	118	118	119	117	116	115	113	112	112
24	118	117	112	112	114	115	118	119	122*	122*	118	116
25	115	117	116	116	116	119	126*	130*	130*	131*	124*	120
26	90*	97*	102*	98*	96*	97*	93*	94*	97*	100*	102*	106
27	98*	100	105	105	105	104	99*	99*	103	103	100*	100*
28	89*	111	106	100*	103	101*	101*	99*	93*	90*	96*	97*
29	106	104	102*	103	104	108	106	105	107	109	111	112
30	106	107	107	110	106	106	104	108	107	109	108	104
31	108	111	109	108	108	108	109	106	102	106	110	111
Monthly mean	110·1	111·6	111·7	111·4	111·9	111·5	110·5	110·1	110·1	110·3	110·1	110·1
Normal	112·5	112·8	112·7	111·7	111·8	112·7	111·7	111·2	110·4	111·0	112·3	112·3

HORIZONTAL INTENSITY—Continued.

magnetometer of the Los Angeles Magnetic Observatory.

readings referred to standard temperature of magnet. Increasing numbers indicate increasing force.]

MAY, 1885.

13^h	14^h	15^h	16^h	17^h	18^h	19^h	20^h	21^h	22^h	23^h	Mid-night.	Daily mean.
114	116	116	115	115	116	116	116	116	114	111	113	113.6^{d}
114	110	107	109	112	112	113	113	114	115	116	116	112.6
110	112	114	114	114	116	118	116	117	116	112	114	113.9
119	116	115	114	113	111	111	111	115	109	111	114	114.1
114	113	110	105	105	107	105	107	110	112	113	114	111.3
118	117	114	112	109	111	112	112	113	114	114	111	113.1
116	114	114	111	109	111	110	109	110	115	112	112	112.6
116	114	112	111	112	114	115	115	115	114	116	115	112.9
118	114	114	114	116	112	112	112	109	114	124*	122*	116.1
109	113	113	115	115	114	119*	117	118	111	106	104	114.7
102*	101*	99*	98*	93*	92*	91*	88*	87*	106	96*	96*	100.9
111	111	111	106	97*	105	110	109	108	110	111	109	108.8
89*	90*	84*	76*	75*	82*	90*	93*	94*	95*	99*	100*	97.6
101*	104	103	102	102	102	102	103	102	104	105	106	102.0
98*	101*	101*	104	98*	104	106	106	106	107	108	107	104.9
113	114	114	110	100	106	110	106	109	108	110	110	109.3
110	111	113	112	110	109	109	110	107	113	111	112	111.7
109	107	109	110	109	110	111	110	110	110	113	111	111.8
108	105	107	112	113	112	112	111	112	113	111	112	112.0
120	115	114	112	107	110	108	109	110	111	112	111	114.6
111	112	110	111	112	113	112	110	110	112	112	113	111.9
112	112	113	112	114	112	111	113	113	114	115	116	113.4
108	107	107	107	110	112	113	116	115	116	116	116	114.2
112	109	108	109	110	112	112	112	111	111	111	113	113.9
114	107	112	104	101	102	102	98*	90*	77*	65*	101*	109.7
102*	105	104	103	104	97*	87*	93*	88*	84*	86*	96*	96.7
98*	100*	98*	92*	92*	89*	84*	80*	97*	98*	80*	94*	96.8
98*	99*	100*	100	102	102	101	102	104	103	102	102	100.0
110	103	101*	102	97*	103	103	104	103	100*	104	106	104.7
110	116	110	111	104	103	102	100*	102	105	108	108	106.7
112	111	107	103	105	104	106	108	106	106	107	107	107.4
109.5	109.0	108.2	107.0	105.7	106.6	106.9	106.7	107.1	107.6	107.0	109.1	109.16
112.8	111.0	110.8	108.9	108.9	109.1	109.3	110.3	110.2	110.9	110.7	110.9	

DIFFERENTIAL MEASURES—

Hourly readings from the photographic traces of the bifilar

[Local mean time. 200 divisions plus tabular quantity, one division = 0·000109 in parts of H. All

JUNE, 1885.

[For the explanation of these tables see pp. 53, 54.]

Day.	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	Noon.
1	108	108	108	107	108	110	109	108	109	113	112	115
2	109	109	110	108	109	111	110	107	107	111	120	117
3	110	112	113	113	113	112	108	107	108	111	113	112
4	103	106	108	105	107	110	104	104	108	109	110	113
5	107	107	108	109	110	111	108	109	107	108	110	112
6	109	109	110	110	110	112	111	109	108	110	109	108
7	109	110	112	112	112	113	112	111	111	113	116	118
8	112	113	112	112	113	113	110	110	114	116	117	119
9	115	116	115	114	117	117	115	114	114	115	118	118
10	120*	121*	115	116	117	116	113	114	114	115	112	113
11	114	115	114	116	113	113	112	106	109	111	115	115
12	112	112	110	110	112	113	111	110	111	114	113	113
13	113	112	110	112	112	112	111	109	106	114	115	115
14	110	110	111	112	112	113	111	109	110	109	113	116
15	111	111	111	112	114	115	112	108	102	101	106	108
16	109	109	109	110	112	110	111	110	109	111	112	112
17	106	107	107	108	108	109	109	107	106	106	111	114
18	112	113	114	115	116	115	113	110	107	107	106	105
19	107	107	108	107	110	110	108	106	110	113	115	115
20	105	105	102	105	102	122*	117	114	110	103	103	107
21	110	110	110	108	111	113	111	109	108	108	109	113
22	102	104	104	106	107	107	108	107	106	103	102*	105
23	109	102	102	102	103	104	105	104	103	100*	100*	102*
24	106	106	106	106	108	109	110	109	109	110	110	107
25	96*	107	109	106	98*	98*	94*	89*	88*	84*	88*	92*
26	96*	98*	99*	99*	98*	97*	97*	95*	97*	93*	93*	96*
27	102	104	105	105	104	104	104	106	111	111	108	105
28	107	107	108	108	108	108	108	105	105	107	110	110
29	111	111	110	110	110	110	109	108	109	111	112	113
30	112	112	112	112	112	112	110	107	107	110	111	111
Monthly mean	108·4	109·1	109·1	109·2	109·5	110·6	109·0	107·4	107·4	108·2	109·6	110·6
Normal	108·9	109·1	109·4	109·5	110·4	111·2	110·0	108·5	108·5	110·0	111·8	112·2

HORIZONTAL INTENSITY—Continued.

magnetometer of the Los Angeles Magnetic Observatory.

readings referred to standard temperature of magnet. Increasing numbers indicate increasing force.]

JUNE, 1885.

13^{h}	14^{h}	15^{h}	16^{h}	17^{h}	18^{h}	19^{h}	20^{h}	21^{h}	22^{h}	23^{h}	Mid-night.	Daily mean.
115	113	111	109	105	102	100	97*	103	106	107	108	108·0d
118	114	110	105	106	107	108	109	108	109	110	110	110·1
113	115	116	113	103	96*	101	107	105	103	107	110	109·2
113	109	104	103	101	103	103	104	103	105	107	106	106·2
113	112	110	105	107	104	106	107	108	109	109	109	108·5
108	108	107	107	106	107	109	109	110	110	109	110	109·0
116	113	109	107	106	106	109	110	110	110	111	112	111·2
117	114	113	110	110	107	106	109	108	110	112	114	112·1
116	119	116	113	116*	117*	114	115	117*	116	117	118*	115·9
115	107	111	110	107	106	108	109	110	110	113	113	112·7
116	114	110	106	107	108	107	104	104	113	106	107	110·6
115	118	115	111	109	106	107	109	109	110	111	113	111·4
118	116	111	106	106	106	105	108	108	109	111	110	110·6
117	116	116	112	112	110	110	109	104	106	111	109	111·2
113	115	111	106	101	104	104	105	107	107	106	106	108·2
108	107	106	104	103	105	106	107	108	105	105	106	108·1
112	110	107	109	108	109	108	108	110	110	111	111	108·8
104	100*	102	104	102	105	106	103	102	109	108	105	107·6
113	112	108	106	108	110	110	111	112	112	111	102	109·6
110	107	106	106	103	102	102	104	105	110	108	110	107·0
115	115	113	109	110	105	106	107	104	104	102	104	108·9
105	99*	99*	95*	92*	96*	101	104	104	105	108	108	103·2
105	108	110	108	107	104	105	105	107	106	107	107	104·8
107	107	126*	118*	99	99	97	97*	93*	93*	97*	105	105·6
83*	87*	91*	88*	82*	81*	81*	81*	89*	87*	101	92*	91·3
96*	96*	93*	93*	94*	95*	98	100	102	102	101	102	97·1
105	106	105	105	106	106	106	110	106	105	107	107	106·0
110	111	112	111	109	109	110	111	110	111	111	111	109·0
110	108	106	109	110	109	106	109	110	110	111	112	109·8
113	116	114	112	112	112	113	114	113	114	113	113	112·0
110·6	109·7	108·9	106·7	104·9	104·5	105·1	106·1	106·3	107·2	108·3	108·3	108·12
112·1	111·9	110·0	107·9	106·3	106·0	105·9	107·7	107·0	108·4	108·7	108·6	

DIFFERENTIAL MEASURES—

Hourly readings from the photographic traces of the bifilar

[Local mean time. 200 divisions plus tabular quantity, one division=0·000109 in parts of H. All

JULY, 1885.

[For the explanation of these tables, see pp. 53, 54.]

Day.	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	Noon.
1	116	116	115	115	114	119	114	99	103	[102]	[101]	99*
2	109	108	108	108	108	109	107	104	100	105	110	108
3	109	109	110	111	112	112	111	109	105	106	110	114
4	119	118	119*	119	116	115	116	111	108	109	109	109
5	119	117	117	119	117	118	114	112	114	111	112	116
6	110	108	109	109	112	112	110	105	104	106	109	111
7	108	110	108	108	110	114	109	108	106	104	108	109
8	107	107	109	109	111	110	110	[109]	110	107	110	110
9	115	114	114	114	115	117	115	113	111	107	108	111
10	110	110	111	111	111	111	106	103	104	106	106	107
11	115	115	121*	114	114	114	109	103	106	112	111	109
12	111	110	112	111	112	111	109	102	102	110	114	115
13	109	110	110	110	109	111	110	110	111	112	112	112
14	112	110	110	109	110	111	109	109	106	104	102	107
15	109	110	111	113	115	115	116	111	105	106	106	108
16	112	111	110	110	109	109	108	107	109	116*	124*	120*
17	110	111	112	113	112	112	111	111	110	109	110	121*
18	109	112	108	118	111	108	107	105	102	97*	95*	98*
19	109	112	107	109	108	109	107	104	102	99	102	106
20	109	109	108	108	108	111	109	104	102	102	103	104
21	108	108	109	110	110	110	107	102	103	108	109	108
22	110	111	109	108	108	109	108	104	102	108	110	112
23	109	110	109	109	108	108	106	104	104	104	106	107
24	108	108	108	109	110	112	112	109	111	116*	117	112
25	114	103	105	106	106	109	103	100	105	111	110	108
26	107	107	108	107	107	105	102	98	99	102	104	106
27	108	108	109	109	110	112	111	106	102	107	109	110
28	110	106	107	106	112	109	108	108	104	106	112	112
29	109	108	109	109	110	110	109	107	103	102	108	116
30	106	106	106	107	108	107	106	103	104	106	110	112
31	108	108	109	109	110	111	109	101	106	112	113	117
Monthly mean	110·4	110·0	110·2	110·5	110·7	111·3	109·3	105·8	105·3	106·8	108·7	110·1
Normal.	110·4	110·0	109·6	110·5	110·7	111·3	109·3	105·8	105·3	106·5	108·7	110·2

HORIZONTAL INTENSITY—Continued.

magnetometer of the Los Angeles Magnetic Observatory.

readings referred to standard temperature of magnet. Increasing numbers indicate increasing force.]

JULY, 1885.

13^h	14^h	15^h	16^h	17^h	18^h	19^h	20^h	21^h	22^h	23^h	Mid-night.	Daily mean.
104	104	104	103	102	101	102	103	103	104	104	106	106·4[d]
106	108	107	107	108	108	108	108	109	108	108	108	107·4
115	114	115	114	116*	115*	110	111	112	112	116	116	111·8
110	112	112	110	108	111	114	115	113	117*	114	117	113·4
112	108	102	103	100	104	102	97*	95*	103	107	106	109·4
108	103	101	100	97	101	104	104	107	108	107	108	106·4
110	111	109	106	105	106	106	104	106	104	103	112	107·7
112	113	110	106	109	108	110	111	111	112	113	114	109·9
112	113	113	111	108	110	114	114	112	113	109	110	112·2
111	112	111	109	109	107	107	111	110	112	113	114	109·3
109	109	109	103	105	105	108	109	109	111	109	112	110·0
115	114	109	106	105	106	103	103	101	104	108	108	108·4
111	109	109	106	104	107	110	109	109	109	109	110	109·5
110	114	114	111	108	107	108	108	107	108	109	109	108·8
106	107	107	107	106	107	108	106	105	108	110	110	108·8
117	117	115	109	105	108	109	110	110	111	109	109	111·4
130*	135*	113	113	117*	100	109	111	109	108	107	107	112·5
104	107	109	104	103	106	102	106	108	108	109	110	106·1
114	113	111	109	105	105	105	104	105	106	108	108	107·0
103	105	105	103	106	107	106	108	106	106	106	109	106·1
105	106	105	101	102	105	107	108	107	108	109	109	106·8
107	106	102	101	102	104	107	107	106	107	108	109	106·9
106	107	107	108	110	109	108	108	108	109	110	109	107·6
110	105	106	106	105	99	100	98	99	106	108	111	107·7
106	102	95*	99	95*	96	103	103	102	106	106	107	104·2
106	105	101	96*	97	99	102	101	104	102	103	107	103·1
111	107	104	109	110	105	103	102	105	106	106	112	107·5
110	108	104	101	99	101	105	107	107	106	106	108	106·8
116	118	106	103	96	95*	95*	94*	101	103	105	104	105·7
114	115	112	106	104	103	105	106	105	106	107	107	107·1
124*	123*	119*	113	112	108	108	105	98	100	107	108	109·9
110·8	110·6	107·9	105·9	105·1	104·8	106·1	106·2	106·0	107·4	108·2	109·5	108·25
109·7	109·4	108·0	106·2	104·6	104·8	106·5	106·9	106·4	107·1	108·2	109·5	

DIFFERENTIAL MEASURES—

Hourly readings from the photographic traces of the bifilar

[Local mean time. 200 divisions plus tabular quantity, one division = 0·000109 in parts of H. All

AUGUST, 1885.

[For the explanation of these tables see pp. 53, 54.]

Day.	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	Noon.
1	115*	117*	110	111	109	108	110	107	103	102	104	107
2	97	106	105	107	106	105	104	98	98	101	107	107
3	102	104	105	107	106	107	105	103	104	107	109	111
4	105	105	105	106	106	103	100	97	100	108	111*	109
5	108	105	105	105	106	106	107	103	104	100	98	102
6	108	107	108	107	108	107	107	104	102	102	102	103
7	99	114*	104	102	104	103	100	102	111*	114*	108	106
8	106	103	103	102	105	103	102	98	97	98	98	98
9	105	107	106	106	106	105	102	98	101	105	108	108
10	110	105	102	103	105	104	104	105	105	104	103	101
11	106	107	106	106	107	110	107	109*	113*	114*	114*	113*
12	107	106	102	106	107	109	106	102	101	101	100	98
13	106	106	106	105	105	106	105	99	101	104	106	110
14	107	110	108	109	108	109	107	102	101	100	100	104
15	102	104	104	105	105	106	106	102	98	99	101	105
16	102	104	99	105	106	105	103	100	100	100	98	98
17	103	104	105	105	104	104	100	96	96	97	99	102
18	105	105	105	105	105	105	103	97	95	95	99	104
19	106	104	106	104	105	106	104	102	99	99	100	106
20	103	104	104	105	105	106	102	99	103	108	108	111
21	104	101	102	101	102	104	100	101	102	100	101	101
22	100	102	101	102	102	102	99	95	92	96	99	100
23	102	103	103	103	102	102	98	96	98	100	100	100
24	103	101	102	102	102	102	98	92	93	94	96	101
25	104	103	101	103	102	102	99	94	99	101	103	106
26	99	99	97	104	100	102	98	94	90	94	96	97
27	104	103	105	105	106	105	102	98	95	99	101	102
28	102	100	101	102	109	100	102	95	95	90*	89*	88*
29	93*	94*	93*	97	99	100	98	95	86*	92	92*	89*
30	100	97	98	99	99	99	94	92	94	99	98	99
31	101	100	100	99	100	100	97	94	91	86*	89*	93*
Monthly mean	103·7	104·2	103·3	104·1	104·5	104·4	102·2	99·0	98·9	100·3	101·2	102·6
Normal	103·7	103·8	103·6	104·1	104·5	104·4	102·2	98·7	98·5	100·2	101·6	103·6

HORIZONTAL INTENSITY—Continued.

magnetometer of the Los Angeles Magnetic Observatory.

readings referred to standard temperature of magnet. Increasing numbers indicate increasing force.]

AUGUST, 1885.

13h	14h	15h	16h	17h	18h	19h	20h	21h	22h	23h	Mid-night.	Daily mean.
106	103	103	93	90*	89*	83*	91*	98	97	105	102	102·6d
101	102	99	101	101	100	97	98	101	99	109	105	102·3
106	103	104	103	101	101	98	101	100	100	104	102	103·9
108	104	99	100	101	101	98	102	101	105	101	105	103·3
105	106	106	106	101	102	104	104	106	105	103	107	104·3
101	102	105	114*	103	104	102	102	105	95	103	105	104·4
104	104	94	86*	85*	95	100	102	101	99	99	95	101·3
101	98	104	100	100	101	101	100	98	100	104	106	101·1
110	111	109	106	97	97	101	102	105	104	104	105	104·5
101	101	104	104	104	103	104	105	104	106	107	107	104·2
111	105	104	105	105	104	102	104	104	104	107	107	107·3
100	104	105	104	103	102	103	103	104	104	104	105	103·6
110	106	103	102	103	105	107	108	108	108	108	109	105·7
108	106	106	104	105	108	107	108	105	101	99	99	105·0
107	111	109	108	105	107	109	110	108	112*	112*	114*	106·2
100	101	111	100	99	99	103	103	103	103	103	104	102·0
108	110	109	107	104	104	106	106	105	105	106	106	103·8
106	108	107	104	102	104	105	104	105	103	106	105	103·4
108	108	106	105	102	90*	96	101	100	99	102	101	102·5
105	105	99	100	100	93	96	103	99	97	101	106	102·6
100	102	101	98	97	96	97	100	100	100	104	99	100·5
100	99	100	93	95	98	101	101	102	103	102	102	99·4
99	98	98	99	100	102	103	103	102	102	99	101	100·5
106	106	104	101	100	101	102	101	103	104	104	104	100·9
106	104	99	98	98	95	95	97	99	99	100	100	100·3
96	99	98	97	95	97	94	98	99	101	102	102	97·8
97	104	95	96	98	94	98	92*	92*	96	94	113*	99·8
86*	90*	94	84*	88*	96	87*	81*	77*	80*	95	91*	92·6
95	92*	93	91*	91	92	88*	90*	93	88*	94	96	93·0
94*	95	97	97	93	92	95	98	99	98	100	99	96·9
96	99	97	92	95	97	98	100	99	100	98	101	96·7
102·6	102·8	102·0	99·9	98·7	99·0	99·4	100·6	100·8	100·5	102·5	103·3	101·69
103·5	103·6	102·0	100·8	99·9	99·7	100·8	102·4	101·9	101·3	102·2	103·0	

DIFFERENTIAL MEASURES—

Hourly readings from the photographic traces of the bifilar

[Local mean time. 200 divisions plus tabular quantity, one division = 0·000109 in parts of H. All

SEPTEMBER, 1885.

[For the explanation of these tables see pp. 53, 54.]

Day.	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	Noon.
1	99	104	100	102	100	102	99	98	96	97	96	94
2	99	106	100	99	100	102	100	94	94	97	100	99
3	95	96	94	97	97	98	96	92	92	96	100	101
4	97	103	100	96	101	105	105	104	98	91	95	89
5	102	96	96	99	94	95	94	91	94	98	95	96
6	105	98	97	100	96	98	95	91	92	95	93	90
7	103	102	101	103	102	102	98	96	98	98	101	99
8	101	100	101	104	105	104	97	97	95	90	92	92
9	100	101	101	100	101	102	100	98	98	99	100	100
10	105	100	102	102	103	103	98	93	89	87	90	93
11	104	103	102	102	104	106	103	97	91	88	90	92
12	104	103	104	103	104	103	99	95	91	89	90	92
13	103	103	102	103	103	103	100	98	96	98	98	96
14	102	103	104	104	105	104	105	104	100	102	105*	105*
15	99	98	105	104	101	107	107	100	95	93	87	84*
16	86*	87*	88*	91	96	102	97	95	90	86	81*	78*
17	97	94	95	96	97	99	96	94	94	92	90	88
18	96	103	100	99	101	99	99	97	96	94	90	92
19	95	97	99	98	99	99	98	96	93	90	94	96
20	96	98	98	99	100	99	96	92	91	90	91	92
21	100	102	103	103	104	103	100	97	98	97	96	96
22	97	97	98	101	102	102	98	92	96	99	92	88
23	90	106	101	96	98	98	95	100	98	94	89	83*
24	98	98	99	99	99	97	95	93	93	95	95	96
25	93	94	100	99	99	99	96	92	88	90	90	92
26	98	98	97	98	100	98	98	96	94	94	95	95
27	108	98	94	95	96	98	97	94	87	85	87	87
28	93	93	94	95	96	96	94	91	88	90	92	91
29	96	97	97	98	97	97	96	94	92	94	94	94
30	98	97	98	104	96	96	96	93	91	90	96	97
Monthly mean	98·6	99·2	99·0	99·6	99·9	100·5	98·2	95·5	93·6	93·3	93·5	92·9
Normal	99·1	99·6	99·4	99·6	99·9	100·5	98·2	95·5	93·6	93·3	93·5	93·7

HORIZONTAL INTENSITY—Continued.

magnetometer of the Los Angeles Magnetic Observatory.

readings referred to standard temperature of magnet. Increasing numbers indicate increasing force.]

SEPTEMBER, 1885.

13^h	14^h	15^h	16^h	17^h	18^h	19^h	20^h	21^h	22^h	23^h	Mid-night.	Daily mean.
97	98	98	99	99	101	102	98	99	95	100	98	98·7^d
98	99	98	98	98	100	103	102	102	103	98	100	99·5
104*	102	102	101	98	92	96	93	85*	89	94	96	96·1
93	90	90	72*	87*	83*	85*	82*	95	96	98	109	94·3
96	96	96	104	102	99	98	99	99	99	100	105	97·6
90	90	93	98	97	101	101	102	101	99	99	103	96·8
100	103	104	105	101	105	102	101	101	101	101	100	101·1
91	92	93	91	94	97	95	94	96	96	99	98	96·4
101	104	104	100	97	98	99	103	98	100	101	104	100·4
97	101	104	104	103	103	103	102	102	103	103	102	99·7
94	100	103	104	102	100	99	100	101	101	103	103	99·7
97	106*	105	99	100	102	102	102	102	103	102	102	100·0
97	100	103	104	104	104	104	104	101	101	101	102	101·2
102	104	101	98	98	93	98	98	96	97	100	98	101·1
86	90	88*	92	85*	84*	79*	99	84*	95	74*	85*	92·5
84*	92	94	88*	85*	93	95	96	97	98	96	94	91·2
90	92	92	92	94	95	97	99	97	92	94	101	94·5
97	99	99	93	96	98	99	99	97	98	94	94	97·0
98	97	98	94	98	95	95	98	98	97	96	94	96·3
93	95	95	93	97	99	98	98	98	98	96	98	95·8
97	99	100	101	103	101	100	99	90	89	93	97	98·7
90	93	93	96	93	92	90	82*	89	90	97	89	94·0
86	89	80*	83*	80*	87*	92	93	94	94	96	97	92·5
96	96	94	92	91	84*	92	86*	85*	87	88	90	93·3
95	96	95	96	95	94	91	93	93	94	91	96	94·2
94	93	94	96	96	98	97	95	94	92	94	98	95·9
86	85*	87*	86*	88*	88*	84*	86*	89	93	93	92	91·0
87	91	95	92	93	94	94	93	94	94	95	95	92·9
96	96	94	95	95	94	92	95	92	95	94	94	94·9
96	95	97	97	97	96	92	88*	92	92	96	95	95·2
94·3	96·1	96·3	95·4	95·5	95·7	95·8	96·0	95·4	96·0	96·2	97·6	96·42
94·3	96·1	97·5	97·5	97·6	97·8	97·3	98·2	96·6	96·0	97·0	97·7	

DIFFERENTIAL MEASURES—

Hourly readings from the photographic traces of the bifilar

[Local mean time. 200 divisions plus tabular quantity, one division = 0·000109 in parts of H. All

OCTOBER, 1885.

[For the explanation of these tables see pp. 53, 54.]

Day.	1^h	2^h	3^h	4^h	5^h	6^h	7^h	8^h	9^h	10^h	11^h	Noon.
1	98	98	100	99	99	97	94	93	91	91	91	90
2	97	91	94	98	97	97	96	94	94	93	93	93
3	94	97	98	102	101	102	99	97	95	94	90	88
4	95	96	97	97	97	96	94	92	93	94	97	97
5	99	99	100	100	102	100	98	96	93	95	95	97
6	98	98	99	99	98	98	96	94	94	96	97	100
7	98	97	96	100	98	101	100	97	94	92	95	94
8	99	99	98	97	97	98	94	92	90	93	96	98
9	91	93	94	94	97	96	97	91	95	96	102*	104*
10	99	100	100	99	99	99	96	92	89	91	94	98
11	97	98	98	97	97	98	99	96	92	93	95	94
12	93	95	97	100	98	97	97	94	91	86	91	92
13	101	106*	98	96	98	101	101	94	90	87	87	91
14	90	93	98	97	95	100	96	96	91	90	90	90
15	92	90	94	96	97	96	96	93	91	90	86	88
16	89	91	94	95	94	99	96	92	89	91	91	91
17	97	98	97	97	98	99	98	96	94	94	94	94
18	99	98	100	96	96	98	96	92	90	91	91	90
19	96	100	98	99	100	99	100	100	98	95	96	98
20	98	98	99	98	99	99	97	95	92	93	94	95
21	98	98	99	98	98	98	96	91	87	86	91	95
22	92	95	98	99	101	99	100	92	89	91	94	94
23	96	98	93	93	93	93	91	87	87	88	90	92
24	93	95	96	96	96	94	96	92	92	95	95	95
25	95	91	92	94	96	94	96	93	91	90	88	91
26	93	93	95	96	96	96	94	92	90	91	91	93
27	95	103	97	97	99	101	98	94	89	92	93	93
28	100	98	100	101	100	101	104	99	96	91	89	91
29	94	94	94	94	95	95	98	98	92	92	93	94
30	92	96	99	103	103	99	101	99	95	93	92	94
31	94	94	94	96	99	95	97	92	92	93	94	91
Monthly mean	95·5	96·5	97·0	97·5	97·8	97·9	97·1	94·0	91·8	91·8	92·7	93·7
Normal	95·5	96·1	97·0	97·5	97·8	97·9	97·1	94·0	91·8	91·8	92·4	93·4

HORIZONTAL INTENSITY—Continued.

magnetometer of the Los Angeles Magnetic Observatory.

readings referred to standard temperature of magnet. Increasing numbers indicate increasing force.]

OCTOBER, 1885.

13h	14h	15h	16h	17h	18h	19h	20h	21h	22h	23h	Mid-night.	Daily mean.
95	96	96	98	94	96	98	98	100	96	93	92	95·5[d]
95	96	96	92	92	93	95	98	94	93	95	95	94·6
88	91	93	96	96	98	98	97	97	95	96	95	95·7
97	99	100	102	102	102	101	101	100	100	99	99	97·8
100	99	97	97	98	97	96	97	97	97	98	97	97·7
100	101	98	97	97	99	100	100	99	97	97	100	98·0
94	96	96	97	97	97	96	97	98	98	98	99	96·9
100	101	100	101	97	94	77*	92	93	92	90	90	94·9
103	103	101	92	94	97	98	98	98	99	99	98	97·1
99	100	100	100	99	100	100	97	97	95	97	96	97·3
94	97	97	89	84*	87	90	93	93	90	91	91	93·8
91	90	90	96	94	93	94	95	96	96	92	96	93·9
92	96	95	95	96	96	96	94	92	91	95	89	94·9
93	93	90	93	94	93	94	94	91	88	93	105*	93·6
93	95	92	91	86*	85*	85*	84*	83*	85*	94	97	90·8
92	93	96	97	97	96	97	100	99	98	97	97	94·6
94	95	94	98	100	99	100	100	99	100	100	97	97·2
87	88	92	89	93	94	96	96	99	99	98	97	94·4
94	95	93	94	95	97	98	94	96	96	98	98	97·0
96	98	98	99	100	99	99	99	98	99	98	98	97·4
99	100	100	101	104	105*	105*	106*	105*	102	100	97	98·3
94	92	95	93	94	90	92	91	94	94	97	97	94·5
90	92	89	91	92	93	94	95	96	95	94	93	92·3
93	94	96	93	95	96	94	93	94	95	94	95	94·5
95	96	96	96	96	96	93	94	92	93	92	93	93·5
97	96	98	96	96	96	95	95	95	94	98	96	94·7
96	93	93	93	98	93	90	86*	88	92	96	99	94·5
96	95	98	95	99	100	90	94	89	87	91	92	95·7
96	94	97	97	97	96	93	95	91	87	87	92	94·0
91	90	92	92	94	93	85*	84*	85*	88	91	92	93·5
86	89	93	95	95	93	87	84*	89	88	90	92	92·2

94·5	95·3	95·5	95·3	95·6	95·6	94·4	94·9	94·7	94·2	95·1	95·6	95·18
94·5	95·3	95·5	95·3	96·4	95·6	95·3	96·0	94·9	94·5	95·1	95·3	

DIFFERENTIAL MEASURES—

Hourly readings from the photographic traces of the bifilar

[Local mean time. 200 divisions plus tabular quantity, one division = 0·000109 in parts of H. All

NOVEMBER, 1885.

[For the explanation of these tables see pp. 53, 54.]

Day.	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	Noon.
1	96	97	98	99	98	100	96	91	95	90	91	90
2	91	92	94	95	95	95	94	92	88	86	83	84
3	93	94	96	97	98	99	100	98	95	94	94	96
4	98	99	98	100	100	100	98	97	94	94	95	97
5	98	98	99	98	98	98	98	98	98	98	96	92
6	96	97	96	98	99	99	98	97	92	90	90	96
7	98	100	101	102	101	98	97	94	92	90	92	91
8	86	93	93	90	92	93	91	90	88	88	89	91
9	94	95	95	96	97	98	96	93	89	84	86	87
10	89	88	92	97	98	94	92	90	87	88	85	80*
11	94	107*	100	91	95	96	100	91	84*	80*	81*	81*
12	90	89	90	90	90	91	92	91	89	80*	81*	85
13	91	93	95	94	93	94	95	94	92	90	87	88
14	94	94	95	97	96	94	93	91	91	90	89	91
15	95	95	95	95	96	96	98	97	96	93	92	92
16	97	98	98	98	100	100	99	97	95	92	90	90
17	97	98	96	97	97	98	99	99	96	93	93	93
18	98	99	99	108*	106	103	104	101	100	95	84	78*
19	89	89	94	94	93	94	95	99	93	94	91	88
20	91	92	92	94	94	95	95	96	93	90	92	92
21	95	96	94	95	96	96	97	97	94	90	91	94
22	94	98	100	98	98	97	98	94	93	92	94	95
23	98	95	95	95	96	97	98	97	94	91	90	89
24	96	99	96	97	98	98	99	99	99	98	96	95
25	92	94	94	96	98	98	97	96	94	92	93	92
26	105*	95	96	98	96	98	100	102	102	102*	100	98
27	95	96	96	97	96	96	96	98	96	96	94	92
28	96	96	97	100	103	100	102	104	103	100	97	95
29	99	99	99	100	100	101	102	105	107*	104*	102*	100
30	98	98	99	100	100	100	100	101	102	100	96	95
Monthly mean	94·8	95·8	96·1	96·9	97·2	97·2	97·3	96·3	94·4	92·1	91·1	90·9
Normal	94·4	95·4	96·1	96·5	97·2	97·2	97·3	96·3	94·3	92·1	91·4	92·1

HORIZONTAL INTENSITY—Continued.

magnetometer of the Los Angeles Magnetic Observatory.

readings referred to standard temperature of magnet. Increasing numbers indicate increasing force.]

NOVEMBER, 1885.

13^h	14^h	15^h	16^h	17^h	18^h	19^h	20^h	21^h	22^h	23^h	Mid-night.	Daily mean.
90	89	91	93	93	94	93	93	93	92	93	91	93·6[d]
85	87	93	96	98	98	98	97	95	92	89	92	92·0
96	96	97	99	100	100	100	100	100	99	99	99	97·5
99	99	100	100	99	100	100	99	99	100	98	98	98·4
93	94	95	91	94	98	99	97	97	96	95	96	96·4
96	97	99	99	98	98	97	97	97	97	97	99	96·6
87	88	88	86	87	83*	85*	78*	80*	79*	80*	83*	90·0
91	89	92	95	94	92	92	93	93	94	94	95	91·6
88	94	94	86	86*	82*	76*	79*	81*	90	85	85	89·0
84	84	87	86	96	96	98	96	93	82*	93	92	90·3
81*	80*	89	90	85*	89	91	87	87	89	87	91	89·4
87	88	90	92	93	91	91	92	90	91	93	91	89·5
90	91	91	92	90	91	92	92	92	93	93	93	91·9
90	90	95	97	98	96	96	96	95	94	95	94	93·8
92	92	93	94	96	96	96	97	96	96	96	96	95·0
91	93	93	98	99	98	98	97	98	97	97	97	96·3
92	95	97	97	98	98	98	97	98	97	97	97	96·5
68*	84	83	81*	80*	78*	81*	83*	78*	78*	86	87	89·3
90	87	87	92	89	89	89	89	92	90	91	92	91·3
91	91	90	93	94	93	93	93	93	92	93	93	92·7
95	94	93	94	93	92	93	95	94	93	95	94	94·2
95	95	96	96	96	95	95	92	92	93	92	92	95·0
91	95	96	96	97	97	97	97	97	97	97	97	95·4
94	93	93	94	93	94	94	91	88	88	94	91	94·9
92	92	93	96	96	98	96	94	91	92	92	91	94·1
94	94	95	96	98	97	96	94	95	96	95	93	97·3
91	94	96	98	98	96	96	97	97	94	94	94	95·5
93	93	94	96	98	98	98	98	98	98	99	99	98·1
98	97	96	98	100	100	100	100	99	99	99	98	100·1
95	96	99	100	100	99	99	98	99	97	95	99	98·5
90·6	91·7	93·2	94·0	94·5	94·2	94·2	93·6	93·2	92·8	93·4	93·6	94·13
91·7	92·1	93·5	94·5	95·7	95·7	95·7	95·1	94·7	94·3	93·9	94·0	

DIFFERENTIAL MEASURES—

Hourly readings from the photographic traces of the bifilar

[Local mean time. 200 divisions plus tabular quantity, one division=0·000109 in parts of H. All

DECEMBER, 1885.

[For the explanation of these tables see pp. 53, 54.]

Day.	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	Noon.
1	97	100	102	102	104	105*	100	97	92	98	96	97
2	92	94	95	94	96	97	97	97	96	94	92	91
3	93	94	95	95	98	99	100	101	98	96	94	93
4	95	95	95	96	96	96	98	98	96	95	94	94
5	96	96	96	97	98	98	99	100	102	100	98	100*
6	98	96	96	96	96	97	99	97	90	104*	90	89
7	91	92	92	97	98	95	89	99	91	87	87	76*
8	91	96	95	90	90	90	90	90	87	80*	86	83
9	92	90	92	91	91	92	92	91	89	86	84	87
10	93	89	92	93	93	92	94	93	90	88	84	83
11	90	90	90	94	92	93	93	93	91	88	86	86
12	92	92	92	93	93	93	93	93	92	90	87	86
13	93	93	94	94	94	95	96	97	95	91	87	87
14	93	93	96	95	96	98	101	98	96	92	87	82
15	90	92	91	92	94	94	96	99	97	93	88	85
16	92	91	93	93	94	96	96	98	97	95	92	90
17	95	95	95	96	97	96	98	99	98	96	91	88
18	93	90	95	94	93	94	96	98	95	95	93	89
19	91	93	92	93	94	95	97	97	93	94	92	90
20	86	90	90	90	94	92	93	94	92	90	86	86
21	90	92	94	95	94	94	96	95	93	94	93	94
22	93	93	94	95	95	96	95	96	97	94	90	91
23	92	92	92	92	92	93	92	94	94	91	88	89
24	95	95	95	96	96	96	97	96	96	93	89	90
25	98	98	99	100	101	100	101	100	98	91	89	90
26	92	93	97	97	98	97	99	99	98	95	91	90
27	94	94	94	94	94	95	95	96	95	93	92	90
28	95	97	99	100	95	98	97	99	98	96	94	89
29	92	92	92	93	93	92	92	92	92	90	89	88
30	93	94	97	96	97	99	102	101	102	99	96	101*
31	96	97	98	98	99	101	101	103	104	101	98	97
Monthly mean	93·0	93·5	94·5	94·9	95·3	95·7	96·3	96·8	95·0	93·2	90·4	89·4
Normal	93·0	93·5	94·5	94·9	95·3	95·5	96·3	96·8	95·0	93·3	90·4	89·1

HORIZONTAL INTENSITY—Continued.

magnetometer of the Los Angeles Magnetic Observatory.

readings referred to standard temperature of magnet. Increasing numbers indicate increasing force.]

DECEMBER, 1885.

13^h	14^h	15^h	16^h	17^h	18^h	19^h	20^h	21^h	22^h	23^h	Mid-night.	Daily mean.
99*	94	86	90	89	88	83*	82*	84	87	89	90	93·8[d]
92	91	90	92	95	94	95	94	93	93	94	95	93·9
92	92	94	95	96	97	97	96	96	95	95	95	95·7
94	94	94	96	96	98	98	99	98	98	97	96	96·1
100*	103*	103*	101	99	102	102	100	97	94	90	90	98·4
100*	83	85	87	84*	84*	77*	76*	80*	86	83	93	90·2
88	87	89	66*	78*	77*	84*	84*	84	88	86	87	87·2
88	80*	85	82*	84*	83*	82*	89	86	87	91	93	87·4
90	89	86	89	90	89	89	87	89	90	91	94	89·6
86	90	92	92	92	90	89	89	89	90	89	89	90·0
90	93	93	92	93	93	93	93	92	92	92	92	91·5
86	88	93	95	96	96	97	97	96	94	92	92	92·4
89	89	94	95	96	96	97	97	97	96	94	93	93·7
84	90	94	93	92	91	93	92	93	93	91	91	92·7
85	87	93	94	94	95	96	96	97	95	94	92	92·9
89	90	92	94	94	94	95	97	97	96	96	95	94·0
88	91	93	94	94	93	91	89	91	91	90	92	93·4
88	88	88	90	92	92	90	88	90	90	91	91	91·8
89	88	90	91	91	85*	90	91	91	89	88	88	91·3
88	88	89	93	95	95	93	88	87	95	88	87	90·4
93	91	91	91	87	84*	87	89	91	92	91	89	91·7
90	92	92	93	94	94	93	93	93	93	93	92	93·4
86	88	92	94	93	91	91	91	92	93	93	94	91·6
90	92	96	98	97	97	97	95	95	94	96	97	94·9
92	95	98	99	99	99	98	97	96	93	91	90	96·3
90	94	96	98	97	96	93	96	97	96	94	93	95·3
90	94	98	100	100	100	99	99	99	95	92	91	95·1
88	89	90	94	91	91	91	87	91	93	92	92	93·6
90	95	97	98	96	97	96	96	94	93	94	94	93·2
96	92	93	95	98	97	97	96	96	96	96	96	96·9
97	97	97	97	98	99	99	97	98	93	94	95	98·1
90·5	90·8	92·4	92·8	93·2	92·8	92·6	92·3	92·5	92·6	91·8	92·2	93·10
89·6	90·7	92·0	94·1	94·4	94·9	94·3	93·5	93·0	92·6	91·8	92·2	

DIFFERENTIAL MEASURES—

Hourly readings from the photographic traces of the bifilar

[Local mean time. 200 divisions plus tabular quantity, one division = 0·000109 in parts of H. All

JANUARY, 1886.

[For the explanation of these tables see pp. 53, 54.]

Day.	1^h	2^h	3^h	4^h	5^h	6^h	7^h	8^h	9^h	10^h	11^h	Noon.
1	94	95	95	97	99	99	99	102	102	100*	96	95*
2	90	93	92	95	96	107*	104*	106*	103*	101*	98*	92
3	90	90	91	93	94	95	92	97	98	94	87	85
4	91	88	90	92	93	93	97	94	94	88	87	86
5	90	89	91	91	94	92	92	92	91	88	82	82
6	90	88	89	90	90	92	90	90	90	92	90	89
7	93	94	94	94	94	94	92	92	93	90	86	85
8	92	92	92	92	91	92	93	93	93	90	88	97*
9	86	78*	56*	75*	70*	76*	78*	79*	93	78*	37*	41*
10	75*	77*	77*	80*	79*	81*	81*	80*	78*	77*	75*	72*
11	83	84	84	88	86	84	87	87	87	83	79	77
12	86	86	86	87	87	88	86	87	87	85	81	79
13	85	86	86	86	87	88	88	87	86	82	76*	73*
14	88	88	91	89	92	94	92	95	91	90	87	84
15	87	88	88	89	90	92	90	92	90	87	82	78
16	89	86	92	93	90	90	91	93	94	87	81	78
17	90	90	90	90	91	92	93	94	93	90	86	84
18	90	90	91	92	92	93	93	94	95	95	93	92
19	89	88	87	91	96	95	98	90	95	87	82	79
20	83	86	86	86	88	90	90	92	92	92	89	85
21	90	90	89	92	91	91	92	92	92	91	89	87
22	89	89	90	92	92	93	98	96	93	91	88	84
23	88	90	89	88	90	90	91	91	91	90	91	89
24	93	93	94	94	95	96	95	97	96	92	90	85
25	91	91	91	93	94	95	97	99	98	96	93	91
26	94	93	94	94	98	98	98	99	98	96	92	89
27	93	92	95	93	94	94	94	96	98	97	93	89
28	90	92	94	95	97	98	99	101	104*	103*	100*	95*
29	87	104*	85	90	91	93	92	97	98	98	96	94
30	88	90	90	93	96	99	96	96	97	96	92	93
31	91	91	92	91	92	93	94	94	95	92	87	84
Monthly mean	88·9	89·4	88·7	90·5	91·2	92·5	92·6	93·4	93·7	90·9	86·2	84·3
Normal	89·3	89·7	90·3	91·4	92·4	93·9	93·1	93·9	93·6	90·7	88·0	85·6

HORIZONTAL INTENSITY—Continued.

magnetometer of the Los Angeles Magnetic Observatory.

readings referred to standard temperature of magnet. Increasing numbers indicate increasing force.]

JANUARY, 1886.

13h	14h	15h	16h	17h	18h	19h	20h	21h	22h	23h	Mid-night.	Daily mean.
95*	96*	94	90	90	95	96	92	94	93	97	96	95·8d
91	87	90	88	88	87	89	89	91	87	87	88	93·3
86	84	87	90	90	88	80*	86	90	97	84	93	90·0
86	85	88	89	89	89	89	91	89	86	88	91	89·7
86	87	88	87	88	90	90	90	90	92	90	90	89·3
89	88	90	92	93	94	93	93	92	93	93	94	91·0
84	87	90	92	93	93	93	94	94	93	93	92	91·6
99*	101*	100*	100*	97	94	89	84	88	90	95	90	93·0
50*	53*	60*	65*	67*	70*	69*	67*	68*	68*	67*	75*	67·8
72*	73*	78*	80	81	82	82	82	83	82	82	83	78·8
78	82	87	88	86	86	86	84	83	83	85	86	84·3
79	83	86	87	87	87	88	87	86	87	85	85	85·5
76	86	88	91	91	90	90	89	92	88	88	88	86·1
84	86	86	86	87	87	86	86	82	84	88	86	87·9
79	82	83	84	85	84	86	88	88	88	87	88	86·5
80	83	88	90	90	90	90	90	90	90	90	90	88·5
86	88	90	92	92	93	92	92	91	91	90	90	90·4
90	89	89	89	89	90	89	88	84	87	89	90	90·5
77	76*	77*	82	76*	77*	78*	83	83	86	85	85	85·1
86	88	83	88	89	90	90	89	90	90	88	89	88·3
77	83	89	87	78*	88	88	85	83	84	89	89	87·8
86	87	88	90	90	88	87	88	84	87	88	88	89·4
88	89	90	90	91	92	92	92	92	91	92	92	90·4
86	88	87	88	92	92	92	92	92	92	92	91	91·8
86	88	91	94	95	96	97	97	95	93	93	94	93·7
86	88	89	90	92	92	93	92	92	91	93	92	93·0
85	84	88	89	94	93	91	90	91	90	90	91	91·8
94*	95	97	97	102*	95	91	84	83	82	79*	81	93·7
92	91	91	93	88	72*	74*	69*	76*	81	82	91	88·5
89	85	83	86	88	82	92	92	90	91	90	91	91·0
82	82	84	87	90	93	91	92	92	92	92	92	90·2
84·0	85·3	87·1	88·4	88·6	88·4	88·2	87·6	87·7	88·0	88·1	89·1	88·87
84·4	86·3	88·3	88·8	89·8	90·0	90·1	89·0	88·8	88·7	89·1	89·5	

DIFFERENTIAL MEASURES—

Hourly readings from the photographic traces of the bifilar

[Local mean time. 200 divisions plus tabular quantity, one division = 0·000109 in parts of H. All

FEBRUARY, 1886.

[For the explanation of these tables see pp. 53, 54.]

Day.	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	Noon.
1	93	93	92	94	95	97	99	101	99	98	94	90
2	90	91	94	94	94	96	99	100	99	96	94	88
3	97	97	95	95	98	97	100	97	95	97	98	96
4	94	93	95	95	96	98	100	102	102	100	94	93
5	87	93	90	92	92	97	91	94	95	89	87	81*
6	93	93	92	92	92	94	94	95	97	98	96	91
7	92	88	91	94	94	94	96	97	98	97	96	94
8	91	92	95	98	95	91	93	95	92	90	94	92
9	94	95	96	95	95	96	97	97	95	95	94	94
10	83	87	89	91	88	95	92	95	96	93	91	86
11	86	89	94	94	92	94	98	96	95	94	90	77*
12	92	90	91	91	93	94	93	94	94	91	92	90
13	92	93	94	94	95	95	95	94	92	90	88	86
14	93	94	94	95	97	97	97	97	97	95	94	88
15	93	95	94	94	96	95	96	97	97	97	99	98
16	86	91	96	94	94	95	95	95	96	97	95	95
17	85	88	90	90	91	91	94	95	99	99	94	94
18	91	91	92	93	94	93	96	99	92	97	95	88
19	91	92	92	91	92	90	89	94	97	97	93	82*
20	94	92	92	90	92	93	92	95	96	93	91	87
21	92	91	92	92	93	93	91	94	91	84*	86	91
22	92	94	94	93	94	99	96	94	102	96	86	80*
23	90	91	92	93	91	91	92	92	92	92	90	88
24	93	94	94	95	95	95	100	100	98	99	101	98
25	93	97	95	98	97	98	98	98	97	99	98	98
26	96	99	99	98	98	98	100	101	100	98	97	92
27	93	93	96	92	94	93	96	100	98	96	96	94
28	95	95	95	97	97	96	95	95	97	100	99	97
Monthly mean	91·5	92·5	93·4	93·7	94·1	94·8	95·5	96·5	96·4	95·2	93·6	90·3
Normal	91·5	92·5	93·4	93·7	94·1	94·8	95·5	96·5	96·4	95·6	93·6	92·0

HORIZONTAL INTENSITY—Continued.

magnetometer of the Los Angeles Magnetic Observatory.

readings referred to standard temperature of magnet. Increasing numbers indicate increasing force.]

FEBRUARY, 1886.

13^h	14^h	15^h	16^h	17^h	18^h	19^h	20^h	21^h	22^h	23^h	Mid-night.	Daily mean.
92	96	94	95	95	96	96	94	92	90	87	88	94·2d
90	86	90	92	94	94	94	93	95	94	93	93	93·5
92	91	93	94	94	93	91	90	92	93	93	94	94·5
92	89	90	91	91	92	90	92	96	95	92	89	94·2
81*	82	83	82	86	90	91	90	90	90	91	91	89·0
87	88	88	91	92	94	95	92	91	89	92	93	92·5
93	91	92	92	94	94	90	82*	88	88	92	91	92·4
92	91	91	91	93	95	95	95	94	94	93	93	93·1
94	94	95	95	96	97	98	96	95	91	88	86	94·5
86	88	86	88	91	90	70*	70*	71*	76*	84	84	86·2
82	80*	87	86	86	90	91	91	91	91	89	89	89·7
89	86	87	89	90	92	92	91	90	91	92	92	91·1
86	88	90	92	92	93	93	93	93	92	92	92	91·8
88	90	93	96	95	97	97	98	97	95	96	94	94·8
97	97	98	98	94	97	98	99	98	98	96	97	96·6
94	85	78*	77*	81*	79*	75*	84	87	81*	80*	81*	88·0
92	91	88	90	90	88	86	87	89	92	90	90	91·0
92	91	89	82	85	86	75*	81*	85	88	88	90	89·7
85	89	87	86	86	88	88	86	88	89	88	87	89·5
80*	84	87	91	91	90	88	86	88	89	90	92	90·1
89	87	85	86	89	90	89	89	88	87	88	90	89·5
82	79*	81*	86	86	78*	86	87	87	88	88	89	89·0
91	94	94	92	91	92	93	94	94	93	93	93	92·0
96	93	90	94	92	94	96	96	94	95	95	95	95·5
96	97	98	97	98	98	99	98	98	97	95	96	97·2
90	90	91	94	95	95	95	95	95	93	93	92	95·6
93	92	90	90	92	94	94	94	94	93	94	94	94·0
96	97	96	98	97	97	97	95	95	94	94	94	96·2
89·9	89·5	89·7	90·5	91·3	91·9	90·8	90·6	91·2	90·9	90·9	91·0	92·33
90·6	90·3	90·5	91·0	91·7	92·9	92·9	92·2	92·0	91·9	91·3	91·4	

DIFFERENTIAL MEASURES—

Hourly readings from the photographic traces of the bifilar

[Local mean time. 200 divisions plus tabular quantity, one division = 0·000109 in parts of H. All

MARCH, 1886.

[For the explanation of these tables see pp. 53, 54.]

Day.	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	Noon.
1	95	95	95	95	95	96	96	93	95	96	94	92
2	96	95	94	94	95	96	93	92	90	85	84	86
3	98	98	98	100	100	92	96	96	90	83	83	81
4	92	99	95	93	93	94	93	91	91	89	87	84
5	94	93	94	94	95	96	98	98	99	100*	96	93
6	95	94	94	96	95	94	96	101	100*	100*	98*	96
7	91	94	93	92	99	96	93	95	89	90	86	87
8	91	92	91	92	93	93	93	91	90	88	86	88
9	95	94	93	98	97	96	98	96	95	94	94	96
10	94	94	98	100	96	93	97	96	96	98	99*	99*
11	93	95	97	95	98	95	94	93	89	89	88	87
12	94	97	98	98	98	98	98	98	96	93	91	88
13	94	94	96	96	97	97	96	94	94	95	96	93
14	97	97	97	98	98	97	97	96	95	94	95	92
15	94	91	93	94	95	96	96	95	94	95	94	94
16	99	94	93	92	96	92	94	96	92	89	84	86
17	89	92	93	92	93	95	95	94	90	88	85	82
18	84*	87	89	93	94	90	96	95	93	92	85	76*
19	87	87	90	92	90	91	90	89	88	84	87	92
20	104*	88	87	87	90	88	89	87	89	93	95	94
21	89	91	90	95	93	92	91	89	87	87	91	91
22	88	89	96	95	91	90	90	86	82	81	80	80
23	95	95	96	97	97	94	94	88	88	83	80	81
24	90	92	93	94	92	95	94	92	88	85	88	89
25	88	92	92	92	93	93	90	89	86	83	84	87
26	94	94	95	95	96	95	94	93	89	89	91	91
27	93	97	96	95	96	94	93	86	86	88	88	88
28	94	94	96	98	99	94	96	94	93	95	98*	91
29	97	98	93	97	97	94	92	88	87	88	89	90
30	99	123*	80*	82*	70*	74*	73*	59*	56*	51*	34*	39*
31	78*	80*	75*	103	84*	81*	70*	70*	67*	66*	58*	63*
Monthly mean	92·9	94·0	92·9	94·6	94·0	92·9	92·7	91·0	89·2	88·1	86·7	86·3
Normal	93·4	93·5	94·0	95·1	95·2	94·0	94·2	92·8	90·8	89·4	88·6	88·9

HORIZONTAL INTENSITY—Continued.

magnetometer of the Los Angeles Magnetic Observatory.

readings referred to standard temperature of magnet. Increasing numbers indicate increasing force.]

MARCH, 1886.

13^h	14^h	15^h	16^h	17^h	18^h	19^h	20^h	21^h	22^h	23^h	Mid-night.	Daily mean.
93	94	94	93	91	93	94	94	92	93	94	94	94·0d
89	93	99	98	97	96	92	92	96	97	98	95	93·4
83	86	88	89	89	90	87	91	92	90	90	91	90·9
87	90	92	93	92	93	94	94	95	94	91	94	92·1
92	93	94	92	94	95	93	95	92	92	91	93	94·4
93	95	100	91	91	92	94	88	90	93	90	94	94·6
91	88	89	91	92	91	91	91	90	90	89	90	91·2
93	96	94	94	93	94	94	93	93	93	93	94	92·2
96	96	95	93	94	96	97	88	83	92	94	93	94·3
98	98	98	96	96	97	96	96	92	92	90	93	95·9
88	91	94	97	92	93	94	94	94	96	94	93	93·0
86	88	89	89	93	94	94	93	92	91	91	93	93·3
91	93	94	93	94	96	96	97	96	97	95	95	95·0
90	92	96	98	99	99	98	99	97	94	92	92	95·8
90	93	92	94	92	92	92	91	91	89	84	88	92·5
83	87	83	83	82*	85	88	88	90	87	89	85	89·0
81	85	89	91	94	82*	82*	90	81*	81*	87	87	88·3
76*	75*	79*	82	78*	81*	84	86	86	84	78*	82*	85·2
86	63*	79*	62*	82*	71*	81*	78*	80*	95	81*	93	84·1
97	93	93	90	88	90	90	90	92	88	91	90	91·0
90	92	86	84	82*	86	83	90	84	86	89	95	88·9
80*	81*	85	82	88	85	81*	86	85	90	91	87	86·2
82	85	86	90	91	91	91	91	91	85	87	90	89·5
89	88	93	95	94	94	95	88	90	89	93	89	91·2
86	84	90	89	91	92	93	92	90	92	92	91	89·6
94	87	86	84	83*	81*	83	86	92	89	91	90	91·1
90	89	88	84	91	88	91	88	89	89	91	92	90·4
93	94	94	94	94	78*	91	95	94	92	94	90	93·5
92	93	94	96	95	93	91	92	94	96	95	93	93·1
23*	64*	64*	48*	51*	58*	66*	67*	66*	69*	74*	75*	65·2
75*	86	84	74*	75*	66*	75*	74*	71*	73*	82	79*	75·4
86·4	88·1	89·7	88·0	89·0	88·1	89·4	89·6	89·0	89·6	89·7	90·3	90·13
89·7	90·7	91·4	90·9	92·7	92·3	91·8	91·4	91·2	91·2	91·0	91·6	

DIFFERENTIAL MEASURES—

Hourly readings from the photographic traces of the bifilar

[Local mean time. 200 divisions plus tabular quantity, one division = 0·000109 in parts of H. All

APRIL, 1886.

[For the explanation of these tables see pp. 53, 54.]

Day.	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	Noon.
1	80*	89	80*	80*	82*	80*	78*	76*	75*	72*	75*	83
2	85	88	84	82*	85	86	85	83	83	84	83	83
3	86	88	88	89	90	89	88	88	90	92	91	89
4	91	96	95	94	95	94	93	91	89	87	85	85
5	92	93	91	92	92	93	92	87	87	88	87	89
6	93	94	94	94	94	94	92	88	87	89	89	89
7	93	90	91	89	91	92	91	88	91	93	94	92
8	91	92	91	92	92	94	92	89	90	89	86	86
9	94	93	93	94	95	94	91	88	89	90	90	92
10	95	96	96	96	96	96	92	91	91	89	92	92
11	95	98	98	98	100	101	102*	99*	96	93	93	93
12	84	82*	86	91	94	94	94	93	87	76*	82	86
13	86	94	86	85	87	89	87	92	92	91	91	89
14	82	82*	87	92	85	84*	82*	87	86	88	81	77*
15	72*	87	86	86	83*	84*	82*	81	79*	82	82	84
16	87	90	87	86	88	89	87	85	86	84	84	82
17	91	89	89	92	92	92	90	86	87	84	84	85
18	90	89	88	92	91	102	98	98	94	91	90	89
19	90	90	92	89	92	94	87	85	84	84	85	83
20	88	88	93	92	93	92	94	90	89	84	84	83
21	90	89	93	93	92	92	91	88	84	84	85	87
22	92	96	94	93	92	96	95	92	90	90	91	93
23	94	94	95	96	96	96	94	93	93	95	98*	100*
24	97	98	95	95	96	94	91	89	89	91	91	92
25	88	90	91	91	93	94	92	87	85	87	93	94
26	92	92	94	94	96	94	92	90	90	94	96	93
27	96	96	96	96	94	95	95	91	91	92	91	90
28	95	96	97	96	96	97	94	91	92	92	91	88
29	95	97	100	97	99	100	97	96	97	97	96	95
30	97	95	97	97	97	98	96	93	91	90	90	88
Monthly mean	90·0	91·7	91·6	91·8	92·3	93·0	91·1	89·2	88·5	88·1	88·3	88·4
Normal	91·0	92·4	92·0	92·5	93·0	94·1	91·9	89·3	89·3	89·1	88·5	88·4

HORIZONTAL INTENSITY—Continued.

magnetometer of the Los Angeles Magnetic Observatory.

readings referred to standard temperature of magnet. Increasing numbers indicate increasing force.]

APRIL, 1886.

13^h	14^h	15^h	16^h	17^h	18^h	19^h	20^h	21^h	22^h	23^h	Mid-night.	Daily mean.
82	82	82	82	80*	77*	82	83	79*	77*	85	82	80·1d
84	87	88	87	85	86	86	87	88	87	88	86	85·4
86	85	87	89	88	87	91	91	90	91	91	90	88·9
86	87	91	93	91	84	88	91	91	90	88	90	90·2
90	88	90	90	88	89	90	90	90	91	94	92	90·2
92	92	92	92	91	89	92	93	94	95	94	94	92·0
88	89	88	89	88	87	90	88	88	87	90	92	90·0
85	87	89	92	93	92	93	92	92	92	93	93	90·7
91	92	94	95	96	94	94	94	94	95	95	95	93·0
91	93	95	98	98	95	95	94	94	95	94	93	94·0
92	88	88	82	84	84	87	86	80*	82	76*	76*	90·4
83	86	79*	75*	86	74*	74*	87	78*	86	83	85	84·0
87	88	90	81	71*	73*	77*	87	77*	86	74*	82	85·1
84	87	87	68*	70*	64*	64*	66*	66*	72*	95	76*	79·7
87	84	84	82	82	84	83	84	86	86	87	86	83·5
82	80	86	89	88	88	86	87	87	94	87	88	86·5
86	79*	82	85	92	90	91	90	85	84	87	85	87·4
84	83	85	84	89	86	89	90	87	87	87	88	89·6
84	88	94	93	91	89	89	91	92	91	88	84	88·7
83	87	83	83	89	86	77*	87	73*	78*	85	89	86·3
86	92	92	89	87	90	89	94	90	91	91	94	89·7
93	95	94	91	91	92	92	90	89	92	97	95	92·7
101*	100*	95	97	98	97	96	96	95	95	94	97	96·0
96	101*	103*	106*	98	97	98	99	85	87	73*	86	93·6
94	91	91	92	87	90	91	91	91	90	91	92	90·7
91	90	91	91	91	93	93	94	94	95	95	96	93·0
92	95	94	95	96	94	93	93	92	92	97	94	93·8
88	89	91	92	90	92	95	96	95	95	94	93	93·1
94	93	91	90	91	77*	90	95	92	94	94	96	94·7
93	94	94	93	96	96	94	86	92	98	99	97	94·2
88·5	89·1	89·7	88·8	88·8	87·2	88·3	89·7	87·5	89·2	89·5	89·5	89·58
88·1	88·6	89·6	89·5	90·5	90·0	90·7	90·6	90·5	90·7	91·2	90·5	

DIFFERENTIAL MEASURES—

Hourly readings from the photographic traces of the bifilar

[Local mean time. 200 divisions plus tabular quantity, one division = 0·000109 in parts of H. All

MAY, 1886.

[For the explanation of these tables see pp. 53, 54.]

Day.	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	Noon.
1	99	96	91	96	93	96	93	90	90	90	90	92
2	94	96	90	91	91	92	90	92	87	90	90	87
3	95	95	94	93	96	94	93	93	89	88	90	92
4	92	93	96	93	94	94	93	89	88	86	88	89
5	94	94	94	95	95	96	95	91	91	89	88	86
6	98	98	100	100	101	101	101	100*	92	91	93	96
7	97	99	98	98	100	99	97	96	96	98	100*	100
8	100	100	100	101	103	103	100	97	96	93	91	94
9	61*	76*	95	79*	79*	79*	77*	76*	78*	85	89	91
10	85*	90	85*	90	93	88	89	90	90	89	94	96
11	90	93	91	89	89	86	86	83	78*	86	86	85
12	88	91	90	89	92	92	87	82	80*	86	83	85
13	92	95	93	92	96	93	93	88	89	87	88	94
14	100	98	92	91	93	94	93	88	92	91	92	91
15	93	92	92	94	93	92	91	89	89	90	85	87
16	93	94	93	93	94	92	90	86	86	87	89	90
17	96	94	93	99	91	93	91	88	84	85	81*	83
18	89	87	89	90	89	88	82*	80*	82	83	88	92
19	92	92	92	93	92	93	91	89	86	84	85	89
20	95	96	96	97	94	96	97	94	92	92	97	94
21	94	98	96	94	98	94	92	83	86	88	90	92
22	95	96	96	96	98	96	95	90	90	89	91	94
23	96	97	98	98	99	98	96	93	95	94	92	87
24	94	94	96	93	95	97	96	95	91	90	92	96
25	97	96	98	97	98	99	97	96	94	93	92	92
26	97	98	98	99	99	99	97	95	93	104*	102*	98
27	100	100	101	100	103	102	103*	90	92	101*	97	99
28	94	94	95	97	96	97	96	90	88	91	93	96
29	95	93	91	94	94	93	92	90	92	92	92	91
30	93	94	94	94	94	94	93	93	95	95	97	101
31	96	96	94	93	94	96	94	93	94	93	92	93
Monthly mean	93·4	94·4	94·2	94·1	94·7	94·4	92·9	90·0	89·2	90·3	90·9	92·0
Normal	94·8	95·0	94·5	94·6	95·2	94·9	93·5	90·5	90·3	89·5	90·5	92·0

HORIZONTAL INTENSITY—Continued.

magnetometer of the Los Angeles Magnetic Observatory.

readings referred to standard temperature of magnet. Increasing numbers indicate increasing force.]

MAY, 1886.

13^h	14^h	15^h	16^h	17^h	18^h	19^h	20^h	21^h	22^h	23^h	Mid-night.	Daily mean.
91	95	94	94	92	86	91	89	94	88	94	93	92·3^d
92	91	89	85	85	86	90	93	91	94	91	90	90·3
91	92	88	90	88	89	92	93	94	94	93	94	92·1
91	94	94	91	89	89	88	89	91	92	94	92	91·2
89	94	96	94.	90	90	92	91	96	96	97	99	93·0
96	96	98	96	95	94	94	93	93	95	95	96	96·3
100	101	102*	101*	100*	99*	100	100*	100*	99	99	99	99·1
92	91	92	67*	58*	50*	54*	65*	66*	47*	58*	92	83·8
86	80*	86	84	82	83	76*	87	82	78*	86	85	81·7
88	86	90	86	85	84	79*	79*	83	88	84*	86	87·6
84	81*	81*	78*	86	87	87	85	89	97	94	86	86·5
85	89	87	87	87	83	77*	83	90	90	88	90	86·7
97	98	83	90	86	88	92	84	89	89	91	92	90·8
91	90	89	91	87	86	85	89	88	85	102	92	91·3
86	88	86	90	88	91	90	92	91	92	92	93	90·2
90	92	96	94	94	92	92	93	94	93	96	95	92·0
84	87	91	88	90	77*	72*	70*	82	86	100	93	87·4
86	88	90	89	81	84	85	85	84	87	94	92	86·8
91	88	92	90	88	89	92	92	93	93	93	93	90·5
91	92	92	90	90	95	93	91	87	86	92	96	93·1
95	96	93	87	84	84	87	89	90	90	92	94	91·1
97	94	92	91	86	87	90	91	93	92	94	95	92·8
92	95	94	91	90	92	94	94	94	95	93	92	94·1
98	93	93	92	92	93	94	94	93	94	94	96	94·0
93	94	92	90	91	93	94	94	95	95	96	95	94·6
98	93	92	91	89	91	90	90	93	96	96	99	95·7
101	96	93	92	94	97	95	93	94	94	92	93	96·8
94	92	93	92	93	89	91	91	92	91	92	92	92·9
92	92	92	90	92	92	91	93	95	94	92	92	92·3
100	98	95	92	92	92	94	93	93	93	94	94	94·5
94	97	97	95	95	95	95	94	94	95	94	97	94·6
92·1	92·0	91·7	89·6	88·4	88·0	88·3	89·0	90·4	90·3	92·3	93·1	91·49
92·1	92·8	91·7	90·4	89·0	89·3	91·5	90·6	90·9	92·2	93·8	93·1	

DIFFERENTIAL MEASURES--

Hourly readings from the photographic traces of the bifilar

[Local mean time. 200 divisions plus tabular quantity, one division = 0·000109 in parts of H. All

JUNE, 1886.

[For the explanation of these tables see pp. 53, 54.]

Day.	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	Noon.
1	95	94	94	93	96	98	99	98	96	94	95	99
2	95	96	95	95	95	93	90	89	91	94	95	95
3	94	95	95	95	96	94	95	93	97	100	103	98
4	95	94	94	92	93	95	93	94	100	104*	104	102
5	96	101	95	95	103	96	96	94	99	95	92	93
6	96	92	94	92	93	92	94	92	93	87	86*	92
7	93	94	97	94	94	93	92	94	93	92	94	93
8	91	96	94	94	95	98	96	94	94	92	92	86*
9	92	92	94	94	94	94	94	94	92	92	96	99
10	96	96	97	96	95	96	97	95	93	94	96	96
11	94	95	97	98	97	98	100	97	98	103	106*	109*
12	90	93	95	97	101	97	97	88	97	96	92	86*
13	92	91	92	94	94	93	92	88	92	94	92	97
14	94	101	98	93	93	93	90	88	86	88	90	92
15	92	93	91	91	94	93	93	90	92	93	92	91
16	94	94	94	95	95	95	94	90	93	98	100	101
17	106*	95	96	94	96	96	97	97	96	93	91	93
18	94	96	97	96	95	99	96	93	94	93	94	95
19	94	94	95	97	95	96	94	89	89	91	95	96
20	95	94	95	95	96	96	96	94	96	96	96	96
21	96	97	96	96	97	95	93	93	94	94	96	94
22	92	95	93	91	97	93	92	95	90	92	99	101
23	91	92	96	92	94	96	95	96	95	97	96	93
24	90	92	92	96	95	93	89	88	83*	94	97	98
25	92	94	90	88	88	91	90	92	95	[97]	99	98
26	89	89	89	89	90	92	91	92	93	96	97	95
27	93	91	94	93	94	94	96	94	96	96	100	98
28	92	96	93	93	93	92	89	91	95	96	96	96
29	95	94	96	97	97	99	97	97	97	96	96	97
30	73*	79*	78*	82*	81*	82*	83*	84	83*	85*	90	91
Monthly mean	93·0	93·8	93·9	93·6	94·5	94·4	93·7	92·4	93·4	94·4	95·6	95·7
Normal	93·3	94·3	94·4	94·0	95·0	94·8	94·0	92·4	94·2	94·4	95·5	95·9

HORIZONTAL INTENSITY—Continued.

magnetometer of the Los Angeles Magnetic Observatory.

readings referred to standard temperature of magnet. Increasing numbers indicate increasing force.]

JUNE, 1886.

13^h	14^h	15^h	16^h	17^h	18^h	19^h	20^h	21^h	22^h	23^h	Mid-night.	Daily mean.
100	99	96	91	92	94	93	94	93	94	94	95	95·3^{d}
97	98	96	94	93	94	95	96	95	93	92	93	94·1
101	96	90	91	95	94	99*	103*	102*	101*	96	97	96·7
101	99	98	98	94	84	81	87	89	88	90	94	94·3
95	98	95	92	82	79*	83	91	86	91	90	93	92·9
93	92	92	93	93	91	86	91	90	85	89	92	91·2
92	88	86	91	88	88	80*	80*	88	88	91	93	90·7
87	89	86	86	88	89	93	92	98	91	95	92	92·0
96	97	96	92	92	93	94	95	94	94	95	95	94·2
96	95	97	95	94	94	91	92	92	94	94	94	94·8
107*	102	98	96	96	98	98	99	98	97	98	96	99·0
93	89	85	85	83	80*	86	85	90	91	92	97	91·0
96	87	92	91	91	91	90	89	85	90	92	95	91·7
96	97	95	94	93	91	94	94	95	96	92	92	93·1
92	92	91	91	90	90	92	95	93	93	94	94	92·2
102	98	97	95	94	90	90	94	96	93	95	99	95·3
95	94	90	89	92	92	92	93	92	87	89	92	93·6
95	95	90	83	84	90	92	92	90	94	94	95	93·2
95	95	94	90	92	92	91	91	91	92	92	94	93·1
95	95	94	93	94	94	94	91	94	94	95	95	94·7
92	91	91	81*	79*	81*	83	85	83	88	89	89	90·5
106*	100	90	75*	84	79*	86	87	89	91	91	89	91·5
94	94	89	85	83	88	88	91	90	90	95	90	92·1
91	87	78*	76*	79*	82	81	91	84	84	87	92	88·3
93	89	88	87	89	71*	85	84	89	87	90	90	[89·8]
91	87	87	88	88	85	89	90	90	89	96	92	90·6
96	96	91	86	88	90	91	91	92	91	92	90	93·0
95	91	89	90	91	92	94	93	94	94	92	93	92·9
93	93	74*	62*	68*	72*	83	61*	69*	75*	82*	106*	87·3
89	87	73*	76*	71*	80*	82	82	81*	88	84	86	82·1
95·5	93·7	90·3	87·9	88·0	87·6	89·2	90·0	90·4	90·8	91·9	93·5	92·38
94·7	93·7	92·0	90·6	90·1	90·7	89·2	90·9	91·1	91·0	92·3	93·0	

DIFFERENTIAL MEASURES—

Hourly readings from the photographic traces of the bifilar

[Local mean time. 200 divisions plus tabular quantity, one division = 0·000109 in parts of H. All

JULY, 1886.

[For the explanation of these tables see pp. 53, 54.]

Day.	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	Noon.
1	90	91	86	86	88	88	85	82	81	84	82	86
2	85	88	90	88	87	86	82	79	90	90	89	90
3	89	90	90	90	92	86	85	84	82	80	81	88
4	91	91	91	90	90	92	92	85	84	84	87	89
5	88	90	92	93	93	94	92	90	89	91	92	92
6	93	93	92	92	92	93	95	92	90	90	89	92
7	94	93	93	95	94	96	96	94	92	94	96	94
8	93	91	91	94	95	98	95	92	89	87	90	96
9	98	98	97	99	100*	100	96	86	89	90	92	93
10	94	100	96	94	94	96	95	92	91	92	93	93
11	97	92	93	92	93	92	92	90	90	89	90	91
12	91	92	92	94	95	94	95	92	92	91	87	86
13	91	92	92	92	92	91	89	89	90	91	92	91
14	97	96	100*	105*	101*	104*	95	94	94	97*	98*	98
15	92	92	87	88	92	92	92	93	93	94	92	89
16	86	95	92	90	90	90	88	86	85	86	90	96
17	93	93	92	90	89	92	90	90	90	88	91	94
18	93	92	92	92	91	93	93	91	92	90	92	93
19	92	93	97	98	92	96	92	91	83	83	85	84
20	87	90	89	87	88	90	86	91	89	84	80	81
21	92	94	91	91	88	89	89	80	83	83	88	89
22	89	91	90	88	85	88	88	88	86	85	84	85
23	99	88	85	86	87	86	85	86	87	87	85	88
24	89	89	89	87	89	89	87	89	92	92	91	90
25	88	88	90	90	90	91	88	84	82	83	85	88
26	90	92	91	92	92	92	90	88	91	93	94	94
27	87	90	91	90	93	97	96	88	86	88	88	83
28	87	77*	76*	74*	75*	75*	72*	74*	76*	76*	83	84
29	84	84	84	84	84	85	85	82	82	82	83	84
30	85	85	83	85	85	86	84	82	89	92	92	90
31	89	88	87	87	89	89	88	86	82	84	88	88
Monthly mean	90·7	90·9	90·4	90·4	90·5	91·3	89·6	87·4	87·5	87·7	88·7	89·6
Normal	90·7	91·4	90·5	90·5	90·3	91·4	90·2	87·9	87·8	87·8	88·4	89·6

HORIZONTAL INTENSITY—Continued.

magnetometer of the Los Angeles Magnetic Observatory.

readings referred to standard temperature of magnet. Increasing numbers indicate increasing force.]

JULY, 1886.

13^h	14^h	15^h	16^h	17^h	18^h	19^h	20^h	21^h	22^h	23^h	Mid-night.	Daily mean.
90	88	89	81	78	80	81	84	87	87	89	88	85·5[d]
88	84	85	84	86	83	78	75*	78*	82	85	92	85·2
93	91	86	88	88	90	86	87	88	90	94	92	87·9
88	86	88	88	91	89	89	88	89	94	91	89	89·0
93	89	91	86	89	91	92	93	92	92	92	93	91·2
93	93	90	89	88	90	90	91	91	92	91	92	91·4
91	95	94	92	91	93	88	91	91	91	92	94	93·1
97	96	95	93	93	91	94	94	98	96	96	99*	93·9
90	101*	94	94	92	90	92	95	94	94	93	94	94·2
93	94	92	90	84	82	84	87	94	92	94	94	92·1
92	91	89	85	88	89	91	94	92	90	91	93	91·1
87	88	89	89	87	90	90	91	91	92	91	91	90·7
91	90	90	90	88	88	90	93	93	94	94	94	91·1
91	93	89	84	82	84	88	89	91	90	88	90	93·3
89	89	93	91	83	83	83	86	83	95	92	82	89·4
94	91	86	85	82	81	83	82	88	92	89	92	88·3
94	89	93	91	92	90	90	90	90	91	93	92	91·1
97	99*	97	91	79	88	96*	95	94	92	94	86	92·2
76*	86	90	78	76*	75*	79	90	88	83	98	89	87·3
84	87	86	81	80	82	85	82	83	86	86	90	85·6
83	79*	78*	81	81	85	87	87	88	87	85	82	85·8
88	88	88	87	86	86	85	87	92	79*	76*	81	86·3
87	87	90	88	82	84	86	86	88	90	89	90	87·3
89	88	84	87	86	87	89	90	88	88	89	89	88·6
89	90	91	89	89	87	89	91	90	90	91	90	88·5
93	91	92	91	89	89	92	94	92	90	90	91	91·4
79*	66*	59*	69*	64*	53*	64*	53*	72*	68*	68*	82	78·1
80*	73*	80*	79	77	78	81	83	84	85	86	85	79·2
83	82	82	82	84	80	85	83	81	82	84	84	83·1
86	84	83	84	84	86	86	87	88	86	89	88	86·2
84	87	88	86	84	86	87	87	91	90	92	90	87·4
88·8	88·2	87·8	86·2	84·6	84·8	86·5	87·3	88·7	88·7	89·4	89·6	88·55
89·9	89·1	89·4	86·8	85·6	86·3	86·9	88·9	89·6	89·8	90·6	89·3	

DIFFERENTIAL MEASURES—

Hourly readings from the photographic traces of the bifilar

[Local mean time. 200 divisions plus tabular quantity, one division = 0·000109 in parts of H. All

AUGUST, 1886.

[For the explanation of these tables see pp. 53, 54.]

Day.	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	Noon.
1	89	90	90	91	92	93	89	87	83	84	90	91
2	90	88	90	92	91	90	90	89	90	92	91	91
3	92	93	92	94	93	93	91	88	89	89	91	88
4	92	93	93	93	93	92	92	89	89	92	94	96
5	94	94	96	95	95	96	90	86	87	90	91	92
6	94	93	99*	95	95	100*	95	92	90	89	87	89
7	96	94	95	93	98	97	98*	90	90	90	92	97
8	89	90	89	90	90	89	84	79	81	86	89	90
9	89	90	90	89	90	89	87	85	88	89	89	88
10	92	92	93	93	94	94	92	90	89	90	90	92
11	92	93	92	90	90	87	87	84	84	84	82	84
12	97	94	84	84	89	87	87	80	80	81	83	86
13	88	89	88	87	89	88	86	84	85	81	82	78*
14	84	88	89	94	84	85	83	82	80	84	86	80
15	92	88	86	86	85	86	85	82	84	80	82	91
16	85	87	89	90	91	91	91	88	87	90	92	90
17	87	90	87	85	89	87	85	82	82	81	80	86
18	94	94	87	88	91	88	88	84	79	78	76*	71*
19	93	88	85	88	88	85	86	82	79	84	85	87
20	88	88	88	87	90	88	86	82	79	80	82	84
21	89	88	92	88	88	88	85	83	83	82	86	88
22	88	90	90	90	90	90	87	83	81	81	82	86
23	91	91	91	89	92	92	90	89	88	88	86	89
24	88	85	81	83	83	82	79	76	75	80	84	83
25	85	86	87	87	87	86	85	84	82	84	86	87
26	88	89	88	86	87	86	83	81	84	88	88	91
27	87	90	92	87	89	89	85	80	79	79	80	83
28	88	89	89	90	90	90	84	79	82	84	87	89
29	90	89	93	90	91	91	88	82	78	78	80	83
30	89	90	90	90	91	90	86	83	82	83	86	88
31	91	93	92	93	93	92	87	83	83	89	93	93
Monthly mean	90·0	90·2	89·9	89·6	90·3	89·7	87·5	84·1	83·6	84·8	86·2	87·5
Normal	90·0	90·2	89·6	89·6	90·3	89·4	87 1	84·1	83·6	84.8	86·5	88·3

HORIZONTAL INTENSITY—Continued.

magnetometer of the Los Angeles Magnetic Observatory.

readings referred to standard temperature of magnet. Increasing numbers indicate increasing force.]

AUGUST, 1886.

13^h	14^h	15^h	16^h	17^h	18^h	19^h	20^h	21^h	22^h	23^h	Mid-night.	Daily mean.
91	86	80	82	83	86	88	88	90	92	90	89	88·1d
92	92	91	88	86	88	89	92	91	91	92	92	90·3
86	88	87	86	87	90	91	92	92	92	91	90	90·2
95	93	92	91	90	90	92	93	93	93	93	91	92·3
94	95	98*	94	92	92	94	94	94	92	96	94	93·1
87	91	92	92	93	92	92	92	93	91	92	93	92·5
96	81	87	88	90	88	87	84	83	80	92	89	90·6
93	91	93	92	89	90	91	90	89	90	89	90	88·9
87	87	87	87	90	90	92	92	92	91	92	92	89·3
92	90	89	87	88	88	86	85	85	84	84	90	89·5
86	86	87	82	85	75*	85	84	79	78*	88	93	85·7
86	87	80	81	83	76*	75*	84	83	86	93	88	84·8
77*	76*	72*	81	80	82	74*	85	90	80	86	97	83·5
85	84	82	83	78	76*	77*	76*	80	82	84	92	83·2
92	91	88	86	81	81	81	70*	81	80	82	89	84·5
86	81	81	78	80	77*	73*	87	79	89	86	88	85·3
86	90	90	80	77	80	77*	87	82	91	85	86	85·1
81	86	87	86	84	83	77*	82	86	88	84	86	84·5
86	85	82	80	82	81	86	85	85	86	86	85	85·0
86	87	85	87	86	88	87	86	85	85	87	87	85·7
88	88	86	84	83	85	84	85	84	86	88	87	86·2
86	86	86	85	85	88	88	89	88	88	88	88	86·8
91	91	90	93	79	56*	55*	70*	68*	67*	65*	77*	82·4
84	87	84	82	81	82	79	80	85	84	88	86	82·5
84	85	83	79	76	81	82	85	83	93	87	84	84·5
90	86	85	84	82	85	88	87	87	87	89	86	86·5
85	88	89	88	89	88	86	84	85	87	88	87	86·0
89	87	85	86	87	89	88	87	89	89	88	89	87·2
84	84	86	85	86	89	90	88	87	88	90	90	86·7
89	88	86	88	89	90	91	90	91	89	90	91	88·3
93	94	90	88	90	93	93	90	92	90	90	91	90·7
88·0	87·5	86·5	85·6	84·9	84·5	84·5	85·9	86·2	86·7	87·8	88·9	87·10
88·3	87·8	86·6	85·6	84·9	86·9	87·9	87·4	86·8	87·7	88·6	89·3	

DIFFERENTIAL MEASURES—

Hourly readings from the photographic traces of the bifilar

[Local mean time. 200 divisions plus tabular quantity, one division = 0·000109 in parts of H. All

SEPTEMBER, 1886.

[For the explanation of these tables see pp. 53, 54.]

Day.	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	Noon.
1	92	92	94	94	94	93	91	88	85	86	91	93
2	89	90	91	91	90	91	88	84	83	83	86	88
3	91	92	94	92	93	92	90	87	86	86	86	86
4	93	91	94	95	95	95	92	90	88	83	83	86
5	91	92	92	92	92	92	90	88	89	91	93	95
6	91	92	94	93	94	94	92	91	88	88	88	89
7	92	92	93	94	96	95	88	85	77	89	88	93
8	86	87	87	90	91	91	86	81	76	80	88	88
9	87	84	86	91	91	93	87	81	77	81	82	85
10	79	84	93	80*	84	83	81	76	72*	69*	71*	82
11	84	83	82	85	82	84	76*	76	70*	66*	78	84
12	79	88	80*	80*	86	82	86	80	82	78	75*	79
13	87	85	84	86	86	82	83	83	81	79	78	77*
14	79	84	85	87	85	88	75*	77	80	79	77	76*
15	85	82	83	83	83	83	81	80	78	79	79	78*
16	86	88	88	89	89	87	82	79	76	78	75*	82
17	85	85	89	90	85	88	84	80	81	81	83	84
18	83	84	85	87	87	87	83	79	78	80	81	83
19	88	88	89	89	88	88	85	83	81	82	83	88
20	90	90	92	92	91	90	89	87	88	87	88	90
21	94	93	89	91	94	92	90	92	90	88	90	87
22	86	86	86	88	89	88	89	86	85	86	86	85
23	89	91	91	90	91	91	90	89	87	87	87	86
24	88	89	89	90	90	89	88	87	85	88	88	89
25	90	91	92	92	92	90	88	85	83	84	84	88
26	90	90	90	91	91	90	88	85	84	85	87	90
27	89	90	91	90	90	90	88	82	82	85	88	91
28	89	90	91	92	93	92	89	86	84	87	93	95
29	91	90	90	91	91	90	87	84	86	91	93	90
30	91	95	96	92	97	93	89	88	87	88	91	86
Monthly mean	87·8	88·6	89·3	89·6	90·0	89·4	86·5	84·0	82·3	83·1	84·7	86·4
Normal	87·8	88·6	89·7	90·3	90·0	89·4	87·3	84·0	83·1	84·3	85·9	87·5

HORIZONTAL INTENSITY—Continued.

magnetometer of the Los Angeles Magnetic Observatory.

readings referred to standard temperature of magnet. Increasing numbers indicate increasing force.]

SEPTEMBER, 1886.

13^h	14^h	15^h	16^h	17^h	18^h	19^h	20^h	21^h	22^h	23^h	Mid-night.	Daily mean.
94	97	97*	95	90	92	92	92	92	90	90	88	91·7[d]
89	90	92	92	92	92	91	91	91	91	91	90	89·4
86	90	91	91	90	88	93	92	93	93	92	92	90·2
88	91	92	95	93	93	94	94	91	87	90	91	91·0
92	88	88	89	90	91	92	92	93	93	92	93	91·3
90	90	88	88	89	91	92	92	92	92	91	90	90·8
94	91	84	85	85	85	82	88	83	85	86	86	88·2
88	89	89	84	80	88	90	89	81	82	81	89	85·9
87	79	75*	68*	72*	71*	81	79	87	78*	62*	86	81·2
82	76*	69*	67*	66*	67*	76*	72*	82	81	75*	94	77·5
78*	83	75*	79	78	79	87	81	85	76*	78*	79*	79·5
82	79	74*	80	78	79	79*	80	72*	76*	83	82	80·0
73*	72*	69*	71*	76*	78*	77*	74*	86	80	74*	77*	79·1
76*	76*	79	78*	80	82	87	82	85	79	89	80	81·0
76*	78*	80	82	82	84	84	86	87	85	87	86	82·1
83	85	83	84	85	85	86	87	85	79	80	91	83·8
82	83	83	83	83	85	85	87	86	87	85	82	84·4
84	85	86	85	85	86	85	85	86	86	88	88	84·4
89	89	90	89	89	90	89	90	90	89	89	88	87·6
89	88	89	89	89	91	88	89	91	92	90	90	89·5
80	77*	79	74*	81	86	87	80	76*	77*	82	87	85·7
85	86	85	81	87	88	88	88	89	89	89	90	86·9
85	86	87	89	89	89	85	85	86	88	89	88	88·1
90	90	90	90	89	91	91	91	89	90	90	90	89·2
88	90	90	90	87	90	91	91	92	91	91	91	89·2
92	93	92	92	91	91	91	91	91	90	90	90	89·8
92	93	93	90	91	91	90	90	89	90	91	90	89·4
95	94	95	95	91	91	91	92	92	91	91	90	91·2
95	101*	92	89	89	90	91	85	87	89	89	92	90·1
84	84	84	81	80	80	83	88	87	87	87	86	87·7
86·3	86·4	85·3	84·8	84·9	86·1	87·3	86·8	87·2	86·1	86·1	87·9	86·54
87·9	88·0	87.5	87·5	86·4	87·7	88·4	87·8	88·1	87·4	88·2	88·5	

DIFFERENTIAL MEASURES—

Hourly readings from the photographic traces of the bifilar

[Local mean time. 200 divisions plus tabular quantity, one division = 0·000109 in parts of H. All

OCTOBER, 1886.

[For the explanation of these tables see pp. 53, 54.]

Day.	1^h	2^h	3^h	4^h	5^h	6^h	7^h	8^h	9^h	10^h	11^h	Noon.
1	87	89	89	89	88	88	87	84	80	83	87	89
2	88	89	89	90	90	89	88	83	82	85	89	88
3	89	88	88	90	91	88	87	82	82	82	82	83
4	88	89	90	90	89	89	89	86	83	83	85	85
5	89	90	91	90	90	93	92	89*	90*	92*	94*	92*
6	84	91	84	88	90	88	95*	89*	84	85	89	74
7	88	78	83	87	88	83	83	75	81	81	80	83
8	76	70*	74*	81	84	84	76	66*	59*	72	75	78
9	76	79	80	85	82	84	75	70*	66*	71	75	73
10	83	82	77	79	79	78	77	73	70*	60*	66*	71*
11	80	83	83	78	81	80	76	74	74	77	79	80
12	91	85	81	78	80	82	82	79	75	77	78	78
13	80	82	84	82	84	83	80	76	72	79	82	80
14	82	80	83	86	81	82	80	74	77	80	80	80
15	85	83	82	82	84	84	82	80	78	78	80	82
16	80	83	82	83	84	83	83	79	79	80	82	81
17	83	84	83	84	86	87	89	82	82	81	81	82
18	85	89	87	86	86	91	90	83	79	83	83	83
19	69*	83	73*	81	78	79	78	79	79	82	85	86
20	86	87	86	85	86	87	87	86	83	86	93*	92*
21	87	85	85	91	86	85	86	83	81	83	79	82
22	84	84	84	85	86	86	85	80	77	78	78	81
23	84	84	84	85	85	84	81	80	77	79	79	82
24	84	85	86	86	87	87	86	83	80	77	79	82
25	85	87	92	90	89	89	88	86	86	88	88	86
26	86	87	87	87	87	86	84	80	76	80	85	79
27	83	83	86	87	87	88	87	75	78	82	80	81
28	84	87	84	82	81	82	82	79	76	72	70*	67*
29	80	81	82	83	83	81	79	74	77	75	77	78
30	85	85	82	83	82	83	82	81	78	76	74	73
31	84	83	84	84	84	85	84	82	80	76	75	75
Monthly mean	83·7	84·4	84·0	85·1	85·1	85·1	83·9	79·7	78·1	79·5	80·9	80·8
Normal	84·2	84·8	84·8	85·1	85·1	85·1	83·5	79·9	79·1	79·7	81·0	80·9

HORIZONTAL INTENSITY—Continued.

magnetometer of the Los Angeles Magnetic Observatory.

readings referred to standard temperature of magnet. Increasing numbers indicate increasing force.]

OCTOBER, 1886.

13^h	14^h	15^h	16^h	17^h	18^h	19^h	20^h	21^h	22^h	23^h	Mid-night.	Daily mean.
90	89	87	86	83	83	86	88	87	86	86	85	86·5[d]
83	83	80	78	84	86	87	87	88	88	87	88	86·2
83	85	86	86	88	88	89	89	88	89	88	89	86·7
87	88	87	88	89	88	90	88	90	89	90	91	88·0
91*	86	88	92*	92*	94*	90	88	82	89	86	94*	90·2
70*	58*	54*	72*	60*	69*	67*	79	70*	78	70*	86	78·1
82	69*	81	75	79	76	69*	69*	68*	65*	74	87	78·5
74	66*	71*	63*	67*	68*	70*	66*	75	81	76	74*	72·8
67*	66*	68*	69*	74	76	74*	83	76	76	83	77	75·2
76	70*	74	69*	71*	74	74*	80	73	78	83	79	74·8
78	77	81	75	71*	74	76	79	81	81	81	82	78·4
79	77	76	78	78	79	80	80	79	79	81	81	79·7
86	83	79	78	76	78	77	76	77	80	84	78	79·8
80	77	79	82	80	77	80	81	78	76	76	78	79·5
84	85	85	84	82	81	82	80	79	81	81	81	81·9
80	80	81	82	84	84	82	80	81	81	78	89	81·7
82	83	84	86	87	88	86	88	86	84	84	84	84·4
77	70*	79	75	79	73*	73*	70*	74	80	83	72*	80·4
85	83	83	83	83	83	83	84	83	83	83	85	81·4
91*	91	90	92*	91	89	89	88	89	87	85	87	88·0
81	81	80	79	80	81	80	80	80	83	81	82	82·5
84	84	84	84	83	83	83	84	83	83	83	84	82·9
83	84	85	86	86	86	84	84	84	82	83	83	83·1
86	86	86	88	87	88	88	88	86	86	84	85	85·0
86	86	86	86	85	85	86	86	86	86	87	86	86·9
86	85	84	83	84	86	83	82	83	82	84	83	83·7
85	81	77	78	78	79	80	82	79	77	83	82	81 6
71*	78	81	82	81	75	69*	77	77	79	80	82	78·2
79	81	82	81	81	82	82	81	82	82	81	82	80·2
76	80	83	84	87	86	85	82	78	81	81	83	81·3
77	79	82	83	86	86	85	85	82	83	83	83	82·1
81·3	79·7	80·7	80·9	81·2	81·5	80·9	81·7	80·8	81·8	82·2	83·3	81·93
81·9	82·9	82·5	82·0	82·9	82·3	83·9	83·2	81·6	82·3	82·6	83·6	

DIFFERENTIAL MEASURES—

Hourly readings from the photographic traces of the bifilar

[Local mean time. 200 divisions plus tabular quantity, one division = 0·000109 in parts of H. All

NOVEMBER, 1886.

[For the explanation of these tables see pp. 53, 54.]

Day.	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	Noon.
1	83	83	84	84	84	84	85	85	84	81	81	81
2	86	85	84	87	82	88	90*	82	88*	85	81	84
3	77	80	79	78	79	80	80	79	64*	67*	68	68
4	78	76	77	77	81	79	81	79	76	69	65*	62*
5	75	76	79	76	77	79	74	73	64*	54*	68	72
6	76	76	78	78	74	82	74	72	68*	73	74	60*
7	80	77	76	76	79	77	74	77	77	76	76	77
8.	80	80	77	80	77	78	76	78	80	78	79	80
9	82	81	79	79	80	79	79	78	76	76	76	77
10	79	77	78	77	78	78	78	79	78	75	75	74
11	81	81	82	83	82	81	81	77	77	78	79	78
12	79	78	79	80	80	81	86	78	75	72	72	71
13	76	75	75	79	78	84	81	84	84	81	81	79
14	78	78	79	80	79	79	80	80	78	77	78	77
15	79	79	81	82	79	78	81	79	76	75	72	70
16	77	78	79	80	83	84	83	81	77	78	78	78
17	80	80	82	80	73	82	80	81	78	74	71	64*
18	77	78	78	79	78	79	80	79	78	79	79	80
19	79	80	80	80	83	82	83	82	83	81	79	80
20	69	75	77	73	76	75	75	75	75	75	73	68
21	77	77	79	79	80	80	80	80	78	80	80	79
22	77	77	78	78	80	80	80	81	80	78	79	81
23	74	77	78	78	81	80	80	81	78	78	78	78
24	78	75	75	77	77	72	77	79	78	73	72	69
25	77	74	75	76	78	79	79	78	74	76	76	73
26	78	78	78	78	78	78	77	77	74	73	73	75
27	77	78	78	78	78	79	78	78	77	74	73	72
28	78	78	79	79	79	80	79	77	76	74	74	74
29	80	78	82	84	82	86	84	88	85	81	69	67
30	78	78	83	81	85	78	78	77	76	75	71	64*
Monthly mean	78·2	78·1	78·9	79·2	79·7	80·0	79·8	79·1	77·1	75·5	75·0	73·7
Normal	78·2	78·1	78·9	79·2	79·7	80·0	79·4	79·1	78·0	76·6	75·3	75·5

HORIZONTAL INTENSITY—Continued.

magnetometer of the Los Angeles Magnetic Observatory.

readings referred to standard temperature of magnet. Increasing numbers indicate increasing force.]

NOVEMBER, 1886.

13^{h}	14^{h}	15^{h}	16^{h}	17^{h}	18^{h}	19^{h}	20^{h}	21^{h}	22^{h}	23^{h}	Mid-night.	Daily mean.
82	83*	84*	86*	88*	88*	88*	88*	88*	86	92*	89*	85·0^{d}
77	70	65	57*	61*	73	72	68	71	72	76	81	77·7
66	67	66	72	74	74	73	74	69	82	76	73	73·5
59*	62*	58*	61*	71	68*	66*	73	77	70	71	74	71·2
72	71	65	68	72	78	72	71	81	70	74	76	72·4
48*	64*	64*	66*	73	74	74	71	80	75	76	73	71·8
77	75	77	78	78	76	78	75	77	75	78	82	77·0
75	78	78	77	77	78	79	76	79	80	77	82	78·3
77	74	73	76	77	78	79	78	79	79	75	73	77·5
75	75	79	79	81	79	81	81	81	81	81	80	78·3
77	78	77	77	77	77	78	77	76	77	71	79	78·4
71	70	72	73	73	76	74	75	75	76	76	79	75·9
75	75	77	77	80	79	79	78	79	79	79	79	78·9
78	78	77	82	83	83	82	82	82	81	79	79	79·5
68	74	76	77	72	77	78	77	76	76	76	76	76·4
79	80	81	82	82	82	81	79	78	79	79	81	80·0
72	73	71	74	76	77	76	78	78	78	76	77	76·7
79	74	74	78	79	79	80	76	78	76	77	78	78·0
79	79	81	80	81	83	84	84	83	82	79	92*	81·6
72	72	74	76	78	78	76	75	75	75	76	76	74·5
79	76	78	80	81	79	77	75	77	76	76	76	78·3
81	81	80	80	80	82	82	82	81	78	73	74	79·3
72	65	69	73	72	75	69	67*	65*	71	73	70	74·3
68	72	69	71	74	77	78	76	73	74	78	80	74·7
72	73	71	74	76	75	77	76	73	80	77	76	75·6
78	79	80	79	81	80	80	79	79	78	78	80	77·8
74	72	75	78	79	79	79	79	78	78	78	78	77·0
73	73	77	80	80	80	80	81	80	80	79	80	77·9
67	65	68	70	70	68*	70	68	71	73	72	73	75·0
74	71	69	72	76	76	74	67*	67*	72	67*	80	74·5
73·2	73·3	73·5	75·1	76·7	77·6	77·2	76·2	76·9	77·0	76·5	78·2	76·90
74·6	73·7	74·0	76·3	76·9	77·9	77·2	76·4	77·3	77·0	76·3	77·3	

DIFFERENTIAL MEASURES—

Hourly readings from the photographic traces of the bifilar

[Local mean time. 200 divisions plus tabular quantity, one division = 0·000109 in parts of H. All

DECEMBER, 1886.

[For the explanation of these tables see pp. 53, 54.]

Day.	1^h	2^h	3^h	4^h	5^h	6^h	7^h	8^h	9^h	10^h	11^h	Noon.
1	76	72	74	73	76	75	80	75	78	74	68	68
2	75	74	77	73	80	71	77	75	76	75	66	67
3	74	72	73	72	78	81	77	82	79	78	73	70
4	74	72	73	75	77	78	78	77	70*	73	70	69
5	74	75	73	74	76	76	78	79	78	70	74	75
6	75	79	73	75	76	78	79	77	78	76	72	70
7	76	79	79	78	78	79	81	83	84	78	77	76
8	72	71	70	73	74	75	76	79	80	79	76	78
9	76	76	76	77	78	78	79	79	81	80	76	75
10	76	77	79	79	79	80	81	81	81	78	74	74
11	79	80	80	80	81	83	80	82	84	84	80	87*
12	78	77	77	81	80	81	81	82	83	83	81	81*
13	80	78	81	80	78	80	80	77	79	78	76	72
14	79	81	80	81	80	79	82	81	82	79	72	76
15	80	80	76	77	81	81	82	84	80	74	72	81*
16	75	76	78	78	77	79	80	77	79	77	74	65
17	78	76	75	78	77	78	76	82	85	77	68	72
18	74	75	76	75	77	78	78	82	80	77	72	68
19	80	77	77	77	75	78	80	81	79	78	80	82*
20	73	74	76	76	78	77	78	79	80	79	74	72
21	78	78	78	79	80	79	80	76	82	80	73	70
22	76	76	77	76	76	78	79	80	83	83	77	73
23	74	73	74	74	76	75	74	76	77	77	73	68
24	75	75	74	74	75	76	77	78	77	74	66	67
25	75	75	76	75	76	76	77	79	79	78	75	72
26	79	78	79	83	80	80	83	81	82	76	73	71
27	73	75	76	74	73	74	73	78	78	75	75	72
28	75	75	76	75	76	77	73	77	76	78	70	63
29	69	76	76	77	85	74	80	78	80	73	70	65
30	76	72	74	77	76	74	76	78	76	77	75	73
31	74	76	76	77	76	77	78	80	79	77	73	69
Monthly mean	75·7	75·8	76·1	76·5	77·6	77·6	78·5	79·2	79·5	77·3	73·4	72·3
Normal	75·7	75·8	76·1	76·5	77·6	77·6	78·5	79·2	79·8	77·3	73·4	70·7

HORIZONTAL INTENSITY—Continued.

magnetometer of the Los Angeles Magnetic Observatory.

readings referred to standard temperature of magnet. Increasing numbers indicate increasing force.]

DECEMBER, 1886.

13^h	14^h	15^h	16^h	17^h	18^h	19^h	20^h	21^h	22^h	23^h	Mid-night.	Daily mean.
69	68	64*	71	74	70	67	67	74	70	73	82	72.4[d]
70	61*	67	70	70	66	76	72	71	76	72	74	72·1
68	70	70	76	76	76	75	70	67	70	73	73	73·9
73	73	67	74	74	74	74	72	75	76	72	72	73·4
71	71	69	71	68	69	70	69	74	72	74	74	73·1
72	74	75	74	75	76	72	76	73	75	78	78	75·3
72	68	75	71	68	66	62*	67	62*	60*	61*	62*	72·6
74	76	77	78	78	77	77	76	76	76	76	75	76·0
74	75	77	76	77	76	77	76	74	75	74	74	76·5
74	76	77	78	78	78	77	76	75	75	75	77	77·3
78	79	78	77	78	79	76	77	78	77	77	80	79·7
79	79	75	77	80	78	80	79	80	78	79	78	79·5
72	74	76	78	80	80	77	71	71	82	77	75	77·2
75	76	77	79	79	80	79	78	77	74	77	77	78·3
69	70	72	74	77	78	70	72	74	76	77	74	76·3
69	72	71	72	72	64*	76	76	76	73	74	72	74·2
69	74	76	73	76	75	76	75	71	73	74	76	75·4
72	76	77	72	72	72	75	75	77	76	76	75	75·5
69	72	73	74	76	75	75	75	76	80	76	74	76·6
72	75	76	76	78	79	77	78	78	78	77	77	76·5
69	70	73	76	77	77	78	78	78	78	78	74	76·6
69	69	70	68	73	69	70	69	80	71	71	71	74·3
66	65	62*	67	74	75	74	73	74	73	74	73	72·5
67	71	75	75	74	76	76	75	76	75	76	75	74·1
71	74	78	82	81	82	83	76	75	72	70	73	76·2
74	69	65	73	74	73	74	73	71	72	72	70	75·2
68	65	71	74	74	70	74	74	72	72	82	74	73·6
61*	73	76	77	75	74	70	67	73	70	69	68	72·7
63	66	72	67	68	70	73	67	68	68	76	71	72·2
72	73	72	73	74	76	76	75	74	75	76	76	74·8
68	70	72	76	76	75	75	75	75	74	75	75	74·9
70·6	71·7	72·7	74·2	75·0	74·4	74·5	73·5	74·0	73·9	74·5	74·2	75·11
70·9	72·1	73·4	74·2	75·0	74·7	75·0	73·5	74·4	74·4	75·0	74·6	

DIFFERENTIAL MEASURES—

Hourly readings from the photographic traces of the bifilar

[Local mean time. 200 divisions plus tabular quantity, one division = 0·000109 in parts of H. All

JANUARY, 1887.

[For the explanation of these tables see pp. 53, 54.]

Day.	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	Noon.
1	75	75	76	76	77	77	78	78	78	77	73	70
2	78	78	78	78	78	79	80	78	81	79	74	69
3	76	76	76	79	79	80	80	79	79	75	73	68
4	73	75	72	74	75	74	77	75	75	[72]	[66]	65
5	74	75	74	76	76	77	78	79	78	76	72	72
6	77	77	77	79	80	80	81	81	81	79	74	73
7	72	75	74	76	77	78	79	80	80	79	73	73
8	77	77	78	78	78	80	82	82	81	78	74	69
9	75	75	76	77	78	79	79	79	77	74	72	71
10	77	77	77	78	78	78	78	79	79	78	75	73
11	76	76	78	76	76	78	78	78	78	73	69	71
12	76	75	75	78	77	77	78	79	77	72	68	70
13	75	74	76	75	76	77	77	79	77	74	71	72
14	77	75	79	80	80	79	79	82	78	70	57*	67
15	69	74	72	73	77	76	74	69	71	62*	59	58*
16	72	68	75	70	70	67*	71	69	67*	69	66	72
17	72	73	72	76	73	74	73	69	67*	63*	58*	58*
18	72	74	74	74	75	75	77	69	74	73	69	66
19	71	73	74	72	75	75	75	72	72	68	59	64
20	73	72	71	73	74	74	76	75	71	70	64	65
21	73	74	72	74	75	75	76	77	77	74	67	64
22	77	77	76	79	77	76	82	87*	92*	76	68	70
23	80	72	72	72	75	74	76	78	78	73	67	65
24	77	72	73	73	77	78	76	76	78	75	71	56*
25	76	75	76	75	80	76	73	75	74	71	59	57*
26	76	73	74	74	76	80	76	78	76	71	61	58*
27	78	75	73	74	76	73	73	74	74	71	60	57*
28	74	74	74	76	75	75	76	78	78	73	66	63
29	74	72	72	72	75	75	76	74	75	70	65	60
30	75	74	73	73	74	75	75	77	76	73	65	65
31	74	79	75	74	76	77	79	78	76	73	69	70
Monthly mean	74·9	74·5	74·6	75·3	76·3	76·4	77·0	76·9	76·6	72·9	67·2	66.2
Normal	74·9	74·5	74·6	75·3	76·3	76·7	77·0	76·5	76·8	73·7	67·8	68·3

HORIZONTAL INTENSITY—Continued.

magnetometer of the Los Angeles Magnetic Observatory.

readings referred to standard temperature of magnet. Increasing numbers indicate increasing force.]

JANUARY, 1887.

13^h	14^h	15^h	16^h	17^h	18^h	19^h	20^h	21^h	22^h	23^h	Mid-night.	Daily mean.
70	71	74	77	78	78	78	78	78	78	78	78	76·1d
67	70	76	79	78	79	79	79	80	79	78	77	77·1
68	70	70	71	72	72	69	74	73	71	73	73	74·0
68	68	66	68	72	71	71	70	71	72	74	74	[71·6]
73	76	74	76	77	77	77	76	77	75	75	76	75·7
73	77	77	78	78	81	81	80	80	81	73	72	77·9
76	78	78	78	79	77	79	78	77	77	76	76	76·9
72	77	78	78	79	78	77	78	78	80	77	76	77·6
74	76	77	77	77	78	78	78	79	78	78	78	76·7
75	80*	81	82	82	77	72	76	78	78	78	77	77·6
72	75	76	77	78	78	77	73	69	68	71	75	74·8
75	78	78	76	77	76	76	76	74	75	75	74	75·5
74	78	82*	81	82	81	83*	83	78	77	76	74	77·2
70	73	75	72	68	64*	70	72	64	77	66	73	72·8
63	63	66	72	71	70	71	71	72	72	67	74	69·4
72	67	67	72	74	74	72	74	70	72	72	73	70·6
60	64	63*	71	72	62*	72	74	74	70	83*	73	69·4
62	59*	67	72	73	74	69	70	69	74	79	72	71·3
67	72	74	72	75	72	74	72	72	73	73	74	71·7
67	67	69	69	71	70	70	70	72	72	75	73	71·0
67	71	74	74	74	75	74	73	74	74	76	73	73·2
66	70	74	78	78	77	67	65*	67	60*	63*	68	73·8
58*	67	72	69	60*	64*	72	74	73	72	72	72	71·1
62	59*	71	71	66	72	73	71	69	74	70	71	71·3
67	69	73	73	76	75	72	73	70	74	68	75	72·2
69	70	73	73	67	73	71	71	72	74	74	72	72·2
61	68	73	77	77	76	73	75	73	70	71	71	71·6
63	63	66	72	72	72	72	72	71	70	68	71	71·2
64	64	66	70	71	72	73	73	72	72	71	73	70·9
68	69	72	74	75	76	73	71	70	70	72	73	72·4
69	63	73	74	70	75	76	77	65	70	71	77	73·3
68·1	70·1	72·7	74·3	74·2	74·1	73·9	74·1	72·9	73·5	73·3	73·8	73·49
68·5	70·5	72·8	74·3	74·6	75·2	73·6	74·4	72·9	74·0	73·3	73·8	

DIFFERENTIAL MEASURES—

Hourly readings from the photographic traces of the bifilar

[Local mean time. 200 divisions plus tabular quantity, one division = 0·000109 in parts of H. All

FEBRUARY, 1887.

[For the explanation of these tables see pp. 53, 54.]

Day.	1^h	2^h	3^h	4^h	5^h	6^h	7^h	8^h	9^h	10^h	11^h	Noon.
1	69	69	72	72	75	75	76	75	74	68	62*	58*
2	71	71	74	73	76	73	76	77	77	74	69	67
3	75	76	78	78	78	80	79	79	80	79†	74†	73
4	74	77	77	77	79	80	80	78	78	83	82	79
5	75	79	77	75	77	78	75	78	73	66*	66	68
6	73	73	73	74	75	77	78	78	79	77	74	75
7	77	79	82	76	76	74	78	81	83	81	78	77
8	74	73	76	77	77	76	76	78	78	74	74	76
9	74	75	78	76	73	73	75	74	74	73	73	73
10	70	71	72	73	74	74	78	76	79	83	80	77
11	76	76	75	77	76	76	76	79	82	82	80	78
12	75	76	76	81	74	81	82	84	84	71	61*	70
13	71	74	75	74	78	75	79	80	73	74	69	70
14	74	76	75	75	78	78	78	78	76	75	57*	63
15	71	72	74	75	73	74	74	75	76	75	73	70
16	70	70	73	75	77	79	78	77	77	77	75	72
17	71	73	74	74	76	76	77	77	76	74	72	71
18	73	75	75	75	75	77	78	79	79	76	73	70
19	74	74	74	75	76	78	78	78	76	74	74	72
20	68	72	72	81	78	80	79	84	82	78	77	75
21	78	74	72	73	76	74	75	83	81	80	78	75
22	72	70	71	78	79	76	80	82	79	76	72	68
23	76	73	73	73	72	71	74	73	73	76	73	65
24	71	70	73	75	74	75	77	75	75	71	65	64
25	76	75	75	74	76	76	77	82	81	78	76	74
26	76	74	77	77	78	77	79	79	80	76	74	71
27	81	79	78	79	81	79	75	82	79	79	76	73
28	77	75	78	79	78	78	79	80	81	77	74	75
Monthly mean	73·6	74·0	75·0	75·7	76·2	76·4	77·4	78·6	78·0	76·0	72·5	71·4
Normal	73·6	74·0	75·0	75·7	76·2	76·4	77·4	78·6	78·0	76·3	74·0	71·9

† Eye readings.

HORIZONTAL INTENSITY—Continued.

magnetometer of the Los Angeles Magnetic Observatory.

readings referred to standard temperature of magnet. Increasing numbers indicate increasing force.]

FEBRUARY, 1887.

13h	14h	15h	16h	17h	18h	19h	20h	21h	22h	23h	Mid-night.	Daily mean.
64	66	72	72	73	71	71	72	73	73	69	70	70·5[d]
68	70	73	75	76	77	77	76	76	76	75	75	73·8
70	67	67	62*	63	60*	62*	63	65	68	75	75	71·9
76	78	76	76	78	78	78	76	77	76	76	75	77·7
69	68	70	71	69	73	72	73	74	72	74	75	72·8
75	74	75	75	76	76	76	76	76	76	76	77	75·6
79	77	77	76	73	74	74	74	73	74	73	73	76·6
80	80	81*	82*	81*	80	78	78	72	71	66	66	76·0
71	71	70	68	72	70	70	73	67	68	70	75	72·3
77	79	71	70	67	70	67	72	72	72	80	75	74·1
79	80	80*	74	64	66	70	74	74	74	75	76	75·8
78	72	58*	60*	70	62*	68	68	70	65	69	70	71·9
64	68	68	70	72	75	64	64	64	71	72	73	71·5
69	69	63	57*	62*	72	72	65	64	69	72	70	70·3
64	66	66	69	71	72	72	73	71	72	73	74	71·9
72	68	62	65	68	70	73	75	71	76	70	66	72·3
69	71	74	74	74	74	72	73	73	72	72	73	73·4
69	70	74	75	74	75	76	76	75	74	74	74	74·6
74	73	70	70	69	69	66	75	67	64	60*	66	71·9
75	76	70	71	69	70	72	66	74	64	69	68	73·7
67	66	68	69	69	71	64	64	68	72	69	69	72·3
73	72	70	71	72	70	67	71	71	72	72	69	73·0
62*	60*	63	68	68	69	67	68	71	70	68	73	70·0
64	66	69	72	74	74	75	73	71	76	74	73	71·9
76	75	78	76	76	76	76	75	80	72	71	77	76·2
69	71	69	70	74	76	78	75	75	74	76	75	75·0
75	74	75	74	75	77	78	78	76	76	77	77	77·2
[76]	[76]	[76]	[76]	78	78	75	69	70	72	73	74	[76·0]
71·6	71·5	70·9	71·0	71·7	72·3	71·8	72·0	71·8	71·9	72·1	72·6	73·58
71·9	71·9	70·6	72·0	71·7	73·2	72·2	72·0	71·8	71·9	72·6	72·6	

DIFFERENTIAL MEASURES—

Hourly readings from the photographic traces of the bifilar

[Local mean time. 200 divisions plus tabular quantity, one division = 0·000109 in parts of H. All

MARCH, 1887.

[For the explanation of these tables see pp. 53, 54.]

Day.	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	Noon.
1	74	78	74	76	75	75	78	79	79	83	82	80
2	73	77	76	78	77	75	76	71	81	85	88*	85*
3	76	76	77	78	79	78	77	77	78	80	79	78
4	[80]	[80]	[81]	[80]	[80]	[79]	[79]	[78]	[79]	78	78	79
5	76	77	77	77	78	80	82	82	82	82	77	74
6	74	78	77	79	77	74	77	75	76	75	70	71
7	72	71	72	72	74	73	73	75	78	80	80	78
8	82	74	83	72	74	75	72	75	76	80	80	77
9	74	83	81	74	76	74	73	74	75	73	74	75
10	76	77	79	75	76	74	76	74	73	71	68	70
11	75	73	75	76	75	75	76	76	76	73	72	71
12	75	75	75	75	75	75	74	73	73	75	77	77
13	77	77	77	77	77	77	77	76	78	80	77	79
14	75	77	77	79	79	78	78	78	80	80	80	78
15	76	77	79	77	77	75	77	78	79	80	79	82
16	74	75	78	76	76	75	76	76	75	76	78	75
17	75	79	79	78	78	79	78	77	78	78	80	79
18	79	79	80	79	79	79	77	76	79	82	84	82
19	79	79	81	80	81	81	82	81	81	78	82	82
20	74	79	81	78	82	80	83	78	82	80	78	77
21	79	77	79	79	73	75	76	71	70	74	61*	70
22	78	79	80	77	79	80	79	78	83	70	66*	65*
23	78	74	78	79	78	77	80	75	70	68	67*	68
24	65*	70	76	75	76	76	73	75	73	69	69	70
25	76	77	79	77	77	78	77	76	76	77	77	76
26	78	78	[79]	[78]	[78]	[77]	[77]	76	74	74	74	74
27	78	79	79	79	81	78	79	78	75	76	76	74
28	74	78	78	78	77	81	79	78	74	71	68	68
29	76	78	78	78	78	78	78	78	78	78	75	74
30	80	80	81	81	80	80	82	82	81	80	78	77
31	81	81	81	81	80	80	80	80	81	80	79	78
Monthly mean	76·1	77·2	78·3	77·4	77·5	77·1	77·5	76·6	77·2	77·0	75·9	75·6
Normal	76·5	77·2	78·3	77·4	77·5	77·1	77·5	76·6	77·2	77·0	76·7	75·6

HORIZONTAL INTENSITY—Continued.

magnetometer of the Los Angeles Magnetic Observatory.

readings referred to standard temperature of magnet. Increasing numbers indicate increasing force.]

MARCH, 1887.

13h	14h	15h	16h	17h	18h	19h	20h	21h	22h	23h	Mid-night.	Daily mean.
76	74	73	73	74	75	76	76	73	73	73	76	76·0d
81	79	76	74	74	75	75	74	76	77	76	76	77·3
78	79	78	78	79	79	80	80	[80]	[80]	[80]	[80]	[78·5]
80	81	80	78	78	78	78	78	78	77	75	75	[78·6]
74	74	79	72	71	69	72	70	71	74	71	72	75·5
67	72	70	69	70	70	70	70	70	73	74	72	72·9
76	75	73	74	76	76	76	75	75	78	74	72	74·9
75	66*	62*	63*	66*	65*	70	66	69	71	72	76	72·5
74	71	74	74	74	73	73	73	73	70	73	73	74·2
75	77	76	74	75	74	72	72	71	77	73	75	74·2
75	79	75	74	74	74	74	73	74	73	77	76	74·7
75	78	78	75	74	74	74	74	75	73	76	76	75·0
79	79	78	76	77	78	76	72	73	73	75	77	76·7
76	80	78	80	78	80	79	78	79	77	79	78	78·4
83	83	68	65*	68	68	70	74	75	71	78	75	75·6
73	75	74	73	72	73	74	74	76	76	77	76	75·1
79	77	76	74	76	76	77	77	77	77	77	78	77·5
80	79	80	79	78	76	77	78	76	77	78	77	78·8
81	78	80	88*	86*	83	79	76	78	76	75	75	80·1
74	72	76	76	74	74	72	72	79	75	68	75	76·6
76	78	79	75	76	76	76	75	76	76	76	75	74·9
67	68	73	71	78	76	73	76	76	76	77	73	74·9
71	73	73	60*	65*	67	69	72	70	67	63*	64*	71·1
72	74	75	76	74	73	73	73	75	75	75	76	73·2
75	77	77	76	75	76	78	75	77	76	77	80	76·7
74	74	76	76	77	76	74	72	77	74	75	77	[75·7]
74	75	77	78	78	76	74	77	77	80	75	74	77·0
73	75	77	76	78	77	78	76	75	74	74	76	75·5
74	77	78	78	79	79	79	80	80	80	79	80	77·9
77	79	81	81	81	81	80	80	79	79	79	81	80·0
78	79	80	80	82	82	81	81	81	80	80	80	80·2
75·5	76·0	75·8	74·7	75·4	75·1	75·1	74·8	75·5	75·3	75·2	75·7	76·15
75·5	76·4	76·3	75·6	75·7	75·5	75·1	74·8	75·5	73·3	75·6	76·1	

DIFFERENTIAL MEASURES—

Hourly readings from the photographic traces of the bifilar

[Local mean time. 200 divisions plus tabular quantity, one division = 0·000109 in parts of H. All

APRIL, 1887.

[For the explanation of these tables see pp. 53, 54.]

Day.	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	Noon.
1	81	81	81	83	83	83	83	82	80	79	80	81
2	73	73	74	75	75	78	79	78	78	77	77	77
3	76	78	78	85	83	78	76	76	77	78	76	75
4	80	81	79	80	80	84	83	83	83	79	73	75
5	70	71	72	72	74	80	77	76	77	79	76	58*
6	77	78	78	78	81	78	76	74	74	67	67	65*
7	68	74	75	72	72	69*	70	73	75	74	72	74
8	74	72	76	76	76	76	76	75	70	67	72	70
9	75	77	80	74	74	73	72	70	66	67	70	72
10	74	78	76	77	76	75	74	70	66	65*	63*	64*
11	69	72	85	77	80	78	72	70	68	68	67	64*
12	74	76	76	75	76	75	73	74	72	70	67	64*
13	75	76	78	77	77	78	76	75	75	75	73	73
14	76	79	80	75	77	81	81	80	79	79	80	81
15	71	69	73	75	76	76	76	76	76	76	75	73
16	77	80	78	79	80	81	79	77	74	72	69	69
17	76	77	77	77	77	77	78	74	73	77	77	74
18	79	76	77	79	79	79	75	74	76	77	77	78
19	79	79	80	79	79	79	78	76	75	76	77	77
20	82	79	80	79	80	80	78	76	76	75	76	77
21	86*	80	76	78	80	80	79	77	77	78	78	78
22	80	83	89*	87	83	84	81	81	79	71	73	73
23	79	79	81	79	80	80	79	76	73	75	76	78
24	80	79	78	77	76	78	77	72	70	71	70	72
25	88*	76	78	83	87	84	78	72	71	70	68	68
26	78	79	79	80	81	82	80	80	80	80	76	75
27	82	83	82	82	84	82	82	79	78	78	78	78
28	88*	84	82	84	84	79	76	64*	76	72	76	75
29	73	67*	70	72	73	73	72	70	72	76	75	75
30	77	76	78	77	78	77	74	73	74	74	75	75
Monthly mean	77·2	77·1	78·2	78·1	78·7	78·6	77·0	75·1	74·7	74·1	73·6	72·9
Normal	76·1	77·4	77·8	78·1	78·7	78·9	77·0	75·5	74·7	74·4	74·0	74·9

HORIZONTAL INTENSITY—Continued.

magnetometer of the Los Angeles Magnetic Observatory.

readings referred to standard temperature of magnet. Increasing numbers indicate increasing force.]

APRIL, 1887.

13^h	14^h	15^h	16^h	17^h	18^h	19^h	20^h	21^h	22^h	23^h	Mid-night.	Daily mean.
82	83	85	77	75	71	64*	62*	69	72	71	75	77·6^d
76	81	79	80	81	80	71	64*	74	73	90*	76	76·6
76	74	76	77	76	77	78	79	79	79	80	79	77·8
75	73	63*	68	72	73	73	74	76	69	66*	62*	75·2
67	73	65*	74	66	74	73	76	76	85*	68	71	72·9
71	75	70	68	73	60*	63*	64*	59*	76	76	60*	71·2
74	75	76	75	69	69	62*	68	66	76	68	74	71·7
63*	71	73	72	74	71	73	74	67	66	66*	70	71·7
75	77	76	77	77	74	70	69	69	78	68	70	72·9
69	74	77	74	76	77	74	66	65	67	64*	67	71·2
66	74	75	76	64*	60*	69	72	73	73	72	74	71·6
71	73	73	76	74	75	74	74	74	74	74	74	73·2
73	73	75	74	74	75	79	78	75	68	71	74	74·9
84*	83	80	80	68	09	75	64*	66	58*	78	70	76·0
74	74	75	74	74	76	75	76	74	82	77	77	75·0
69	70	72	76	73	77	77	76	76	74	77	74	75·3
73	76	76	76	75	75	75	76	75	74	73	73	75·5
78	76	80	79	77	74	74	76	77	78	77	78	77·1
79	72	78	80	80	80	81	77	77	71	77	78	77·7
77	78	79	78	78	78	78	79	78	81	81	80	78·5
78	79	78	78	79	75	79	80	78	80	80	81	78·8
78	76	66*	75	76	76	74	66	75	76	78	80	77·5
77	80	78	68	70	68	66	68	70	76	74	76	75·2
76	77	79	78	81	78	79	76	76	77	76	79	76·3
68	68	71	72	72	70	73	75	75	75	77	79	74·9
76	77	76	74	76	79	79	80	80	81	81	82	78·8
81	85*	84	84	82	82	82	83	85*	85*	87*	87*	82·3
70	65*	66*	69	68	60*	68	73	71	72	74	81	74·0
75	75	77	71	68	70	72	70	75	74	77	76	72·8
76	76	78	77	75	75	74	74	73	74	74	79	75·5
74·2	75·4	75·2	75·2	74·1	73·3	73·5	73·0	73·4	74·8	75·1	75·2	75·32
74·3	75·5	76·8	75·2	74·5	74·7	74·6	74·4	73·5	74·7	75·2	75·8	

DIFFERENTIAL MEASURES—

Hourly readings from the photographic traces of the bifilar

[Local mean time. 200 divisions plus tabular quantity, one division = 0·000109 in parts of H. All

MAY, 1887.

[For the explanation of these tables see pp. 53, 54.]

Day.	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	Noon.
1	79	79	78	78	78	76	75	72	71	70	68	72
2	69	72	73	73	78	73	75	74	74	76	73	65*
3	74	73	73	75	76	76	74	73	74	75	75	73
4	76	78	78	78	75	72	71	73	68	66	68	69
5	75	76	74	75	77	77	77	73	71	67	68	69
6	76	75	76	76	76	76	74	72	72	70	71	71
7	76	76	76	76	76	74	73	73	74	71	71	71
8	77	79	78	80	77	78	79	76	75	73	71	72
9	79	78	78	79	78	79	78	77	78	76	76	80
10	78	79	78	79	79	78	80	79	78	75	74	73
11	78	78	77	78	79	77	76	82	79	76	72	74
12	85	88*	86*	88*	87*	88*	85	87*	89*	92*	92*	93*
13	85	79	78	78	80	78	81	79	83	76	74	76
14	75	74	75	77	76	77	80	78	77	74	69	69
15	76	78	80	79	78	78	75	78	78	76	74	72
16	75	77	77	79	78	76	76	73	76	77	76	74
17	78	80	76	76	75	77	75	73	70	72	74	72
18	73	74	75	74	76	76	76	74	73	75	74	74
19	81	75	76	75	76	74	73	73	75	77	77	74
20	76	76	76	76	76	77	76	74	75	78	78	77
21	78	78	79	79	81	81	77	71	71	73	76	78
22	79	78	78	77	77	78	77	74	72	72	71	74
23	80	80	80	82	83	83	80	76	76	76	79	80
24	70	69	72	72	72	74	70	63*	68	72	73	69
25	69	83	73	74	72	73	68	74	75	75	78	78
26	72	70	73	73	74	75	77	75	74	76	76	80
27	80	82	81	82	78	75	72	71	73	78	79	75
28	78	72	72	72	75	75	75	75	71	72	77	80
29	77	77	77	78	78	78	75	75	78	78	76	75
30	77	81	80	79	83	80	79	78	81	79	79	78
31	79	79	79	79	83	80	80	76	78	80	81	77
Monthly mean	76·8	77·2	76·8	77·3	77·6	77·1	76·1	74·9	75·1	74·9	74·8	74·6
Normal	76·8	76·8	76·5	76·9	77·3	76·7	76·1	74·9	74·6	74·4	74·3	74·3

HORIZONTAL INTENSITY—Continued.

magnetometer of the Los Angeles Magnetic Observatory.

readings referred to standard temperature of magnet. Increasing numbers indicate increasing force.]

MAY, 1887.

13^h	14^h	15^h	16^h	17^h	18^h	19^h	20^h	21^h	22^h	23^h	Mid-night.	Daily mean.
72	72	77	78	78	78	79	80	79	75	72	58*	74·8[d]
71	76	74	76	71	58*	70	68	83	69	70	79	72·5
71	69	72	74	72	66	63*	72	70	70	80	75	72·7
69	73	75	70	69	67	61*	69	78	74	74	74	71·9
69	72	75	74	71	70	73	71	75	76	79	76	73·3
74	77	76	79	77	77	71	72	73	75	76	76	74·5
70	73	73	74	76	75	73	73	74	75	76	77	74·0
76	78	77	74	74	76	76	73	74	76	77	77	76·0
81	82	79	78	76	72	74	75	76	78	78	82	77·8
72	72	72	72	73	76	76	75	76	75	76	77	75·9
75	76	78	78	80	79	81	84*	83	80	82	85	78·6
84*	83	76	75	60*	57*	68	76	73	70	78	78	80·7
77	75	72	71	72	72	74	66	67	68	72	74	75·3
72	70	73	72	77	72	71	68	78	70	75	76	74·0
71	73	72	71	71	72	72	75	75	74	80	74	75·1
73	72	72	73	72	74	74	73	75	75	76	78	75·0
73	72	71	70	70	67	69	72	71	68	68	79	72·8
74	78	78	78	79	82*	63*	67	67	72	69	76	74·0
72	69	73	73	74	74	75	74	74	73	75	76	74·5
79	80	82	77	78	76	76	76	76	76	77	78	76·9
78	80	80	78	76	76	78	79	79	79	79	78	77·6
80	79	78	74	74	76	77	77	77	78	79	80	76·5
84*	90*	89*	76	68	64	56*	67	70	70	81	75	76·9
71	66*	70	61*	60*	64	66	64	63*	69	67	78	68·5
73	74	70	69	68	69	72	72	73	73	74	72	73·0
87*	80	76	74	76	76	77	77	78	78	79	78	76·3
77	72	72	73	63*	66	67	70	66	72	70	71	73·5
80	80	78	75	75	74	74	76	76	76	76	76	75·4
74	74	74	73	71	73	71	73	72	73	74	79	75·1
76	74	76	74	75	75	75	72	72	70	76	76	76·9
76	75	75	79	79	79	75	77	78	80	84	78	78·6
75·2	75·4	75·3	74·0	72·7	72·0	71·8	73·0	74·2	73·8	75·8	76·3	75·12
74·2	75·2	74·9	74·4	74·0	72·7	73·4	72·6	74·6	73·8	75·8	76·9	

DIFFERENTIAL MEASURES—

Hourly readings from the photographic traces of the bifilar

[Local mean time. 200 divisions plus tabular quantity, one division = 0·000109 in parts of H. All

JUNE, 1887.

[For the explanation of these tables see pp. 53, 54.]

Day.	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	Noon.
1	74	77	77	77	77	76	78	78	77	74	70	73
2	82	82	79	80	79	77	73	74	79	81	78	80
3	80	80	80	79	79	81	80	77	75	79	79	79
4	80	80	80	80	80	80	78	70	72	78	83	85
5	86	72	80	78	75	80	78	77	74	77	77	74
6	79	82	81	79	80	80	80	80	80	79	80	82
7	78	79	79	79	80	78	76	74	70	78	77	76
8	82	84	87	83	84	85	85	82	77	75	77	80
9	80	81	84	82	80	82	82	80	82	80	78	82
10	85	75	85	78	80	81	81	76	74	73	74	76
11	78	82	81	80	81	81	80	78	75	76	76	79
12	78	79	80	80	82	80	82	80	78	79	79	81
13	74	77	77	78	79	80	78	78	73	70	70	73
14	76	76	77	77	78	79	79	76	75	76	77	80
15	77	78	78	78	78	79	76	73	72	74	75	77
16	76	78	77	77	79	80	76	71	72	72	72	72
17	79	79	80	81	79	81	79	75	73	72	75	78
18	84	83	85	86	85	90*	80	80	81	82	82	83
19	82	85	78	80	79	75	78	79	79	78	75	75
20	82	80	81	79	79	80	81	80	77	78	77	75
21	76	75	79	81	81	80	78	75	79	79	79	78
22	83	78	73	74	73	76	76	75	76	78	73	72
23	76	76	76	76	75	74	74	75	77	78	79	77
24	75	76	77	76	75	75	74	74	70	[72]	74	75
25	76	77	76	76	77	78	77	76	76	75	74	75
26	79	79	80	80	79	80	79	78	79	78	76	72
27	[78]	[78]	[78]	[78]	[77]	[77]	[77]	[74]	73	75	76	75
28	78	78	77	78	78	79	79	78	76	75	73	74
29	79	79	79	80	80	80	81	80	79	78	80	81
30	83	84	86	82	86	89*	86	85	82	77	79	81
Monthly mean	79·2	79·0	79·6	79·1	79·1	79·8	78·7	76·8	76·3	76·5	76·5	77·3
Normal	79·2	79·0	79·6	79·1	79·1	79·1	78·7	76·8	76·3	76·5	76·5	77·3

HORIZONTAL INTENSITY—Continued.

magnetometer of the Los Angeles Magnetic Observatory.

readings referred to standard temperature of magnet. Increasing numbers indicate increasing force.]

JUNE, 1887.

13^h	14^h	15^h	16^h	17^h	18^h	19^h	20^h	21^h	22^h	23^h	Mid-night.	Daily mean.
77	75	75	73	73	73	74	77	78	78	78	78	75·7^d
79	78	74	74	74	77	78	77	79	80	80	80	78·1
81	78	76	76	75	77	78	78	79	79	80	80	78·5
83	77	81	80	78	78	82	82	81	82	77	79	79·4
72	69	68	67	68	69	74	74	80	80	77	78	75·2
82	82	81	79	75	73	75	76	76	76	76	76	78·7
77	76	76	78	77	77	78	78	76	80	79	82	77·7
81	84	83	83	76	77	77	76	80	67*	74	74	79·7
78	79	77	78	75	71	74	77	77	82	77	82	79·2
77	79	80	78	75	75	77	76	77	77	77	79	77·7
79	74	76	77	76	76	76	78	78	78	80	78	78·0
82	84	84	79	70	71	70	67	70	73	73	76	77·4
78	79	75	73	71	71	74	74	74	74	74	75	75·0
80	81	80	79	76	74	74	75	75	76	76	76	77·0
78	78	77	76	76	75	75	75	76	77	75	75	76·2
72	72	73	74	74	76	76	76	76	76	76	78	75·0
77	80	78	77	77	72	75	76	79	84	83	81	77·9
78	81	83	83	80	78	76	78	78	80	82	84	81·7
76	77	78	77	72	75	75	76	78	79	79	82	77·8
76	76	76	77	74	76	76	75	75	74	74	86	77·7
80	77	78	69	74	70	69	71	67*	73	72	77	75·7
70	76	71	73	73	72	71	72	72	80	76	76	74·5
77	75	71	70	72	72	72	74	76	74	72	73	74·6
71	71	72	71	71	73	73	74	74	74	76	77	[73·8]
80	79	79	76	75	71	74	74	74	77	77	77	76·1
72	77	77	78	77	77	75	[75]	[76]	[77]	[76]	[78]	[77·2]
75	76	75	73	78	78	78	78	77	78	78	76	[76·5]
76	77	76	75	75	76	77	75	79	79	78	78	76·8
81	83	79	78	70	74	78	79	77	79	78	86	79·0
81	80	78	76	76	77	78	78	78	78	78	80	80·7
77·5	77·7	76·9	75·9	74·4	74·4	75·3	75·7	76·4	77·4	76·9	78·6	77·29
77·5	77·7	76·9	75·9	74·4	74·4	75·3	75·7	76·7	77·7	76·9	78·6	

DIFFERENTIAL MEASURES—

Hourly readings from the photographic traces of the bifilar

[Local mean time. 200 divisions plus tabular quantity, one division = 0·000109 in parts of H. All

JULY, 1887.

[For the explanation of these tables see pp. 53, 54.]

Day.	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	Noon.
1	79	79	79	80	79	80	79	75	74	75	77	78
2	75	75	77	78	78	79	76	74	70	74	77	79
3	77	77	77	78	78	78	76	75	76	77	76	75
4	80	81	82	82	82	82	80	72	77	77	82	83
5	86	86	86	86	87	88	84	82	80	81†	84†	86
6	74	75	75	78	79	78	74	70	74	73	77	76
7	72	69*	90*	76	79	83	83	75	68	76	82	80
8	71	74	73	73	74	72	75	75	75	74	70	70
9	73	74	73	74	73	74	70	66	65*	72	75	81
10	84	79	79	77	81	80	76	73	74	68	62*	64*
11	77	76	78	78	80	79	76	73	74	75	74	76
12	74	79	74	76	75	73	72	69	71	70	72	74
13	72	71	73	74	74	78	78	75	72	68	71	73
14	72	75	76	78	78	79	76	75	74	76	77	79
15	83	86	82	83	84	83	83	79	76	79	79	79
16	79	79	79	78	79	78	79	76	76	81	82	82
17	76	76	77	78	77	78	78	77	77	77	75	73
18	78	80	81	80	82	79	79	80	82	82	73	71
19	79	78	79	79	78	78	78	77	75	77	77	81
20	77	79	77	76	76	75	74	69	66	74	77	80
21	83	83	81	81	80	80	79	75	78	80	82	80
22	78	78	79	80	80	80	78	76	74	75	80	85
23	80	81	80	79	79	78	77	73	71	76	80	85
24	78	78	78	78	77	77	75	73	80	82	83	80
25	79	80	81	80	79	77	74	75	76	78	80	77
26	78	80	78	78	78	79	77	75	74	75	77	76
27	82	82	87	83	83	83	81	78	76	73	73	77
28	79	80	80	79	79	80	79	76	75	78	79	77
29	80	80	80	80	80	81	78	76	79	81	83	83
30	81	81	80	80	81	82	81	76	72	71	74	80
31	83	81	82	82	82	81	77	74	76	77	78	79
Monthly mean	78·0	78·5	79·1	78·8	79·1	79·1	77·5	74·6	74·4	75·9	77·0	78·0
Normal	78·0	78·8	78·8	78·8	79·1	79·1	77·5	74·6	74·7	75·9	77·5	78·5

† Eye readings.

HORIZONTAL INTENSITY—Continued.

magnetometer of the Los Angeles Magnetic Observatory.

readings referred to standard temperature of magnet. Increasing numbers indicate increasing force.]

JULY, 1887.

13h	14h	15h	16h	17h	18h	19h	20h	21h	22h	23h	Mid-night.	Daily mean.
78	77	75	75	76	76	77	76	77	78	77	78	77·2[d]
80	78	76	74	74	75	76	77	77	77	78	79	76·4
78	77	78	78	77	77	76	77	78	78	78	78	77·1
83	82	80	83	77	78	81	81	81	81	80	81	80·3
87	85	83	77	77	80	77	75	67*	66*	68	69	80·3
72	71	70	67	65*	63*	64*	66*	69	69	66*	63*	71·2
76	75	69	67	63*	66	57*	68	66*	77	71	73	73·4
66*	67*	65*	60*	65*	69	64*	66*	71	71	71	74	70·2
85	85	83	80	75	73	73	76	74	77	76	78	75·2
73	74	73	73	74	71	77	74	75	77	78	81	74·9
79	82	80	78	74	70	69	72	71	71	73	72	75·3
76	75	74	71	69	69	71	72	75	71	70	70	72·6
72	80	71	66	67	67	69	70	72	73	72	74	72·2
78	76	74	72	76	79	80	80	80	80	81	82	77·2
75	78	72	71	74	74	74	74	71	74	77	79	77·9
81	80	79	75	74	74	76	78	78	78	78	77	78·2
75	77	76	75	76	75	79	80	80	80	79	78	77·0
83	82	85	76	78	74	72	73	79	75	78	78	78·3
79	80	71	70	71	72	74	71	71	78	75	76	76·0
81	74	71	73	72	73	75	76	77	78	79	79	75·3
80	76	75	74	73	76	76	76	76	76	76	77	78·0
86	85	84	78	76	76	78	78	79	79	80	80	79·2
87	82	79	71	70	73	76	75	76	76	75	77	77·3
80	79	76	74	73	75	77	77	77	77	78	79	77·5
75	76	75	76	76	76	76	75	73	74	75	77	76·7
73	74	76	78	78	79	80	80	81	82	83	84	78·0
80	76	76	75	74	74	78	79	79	78	78	79	78·5
76	74	76	77	77	80	80	79	79	79	79	80	78·2
80	78	78	76	78	79	80	78	78	77	78	81	79·3
82	84	84	81	79	80	80	80	81	82	82	83	79·9
80	82	82	81	79	80	81	80	81	80	81	82	80·0
78·6	78·1	76·3	74·3	73·8	74·3	74·9	75·5	75·8	76·4	76·5	77·4	76·74
79·0	78·5	76·7	74·7	74·8	74·7	76·4	76·1	76·4	76·8	76·8	77·8	

DIFFERENTIAL MEASURES—

Hourly readings from the photographic traces of the bifilar

[Local mean time. 200 divisions plus tabular quantity, one division = 0·000109 in parts of H. All

AUGUST, 1887.

[For the explanation of these tables see pp. 53, 54.]

Day.	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	Noon.
1	82	82	82	91*	91*	90*	86*	77	64	73	80	84*
2	64*	66*	67	66*	68	68	64*	65	66	68	62*	72
3	73	69	73	73	73	69	68	66	69	71	70	73
4	74	73	75	73	72	74	70	67	72	71	72	72
5	74	82	70	78	76	74	72	74	74	72	71	72
6	78	76	74	72	74	74	72	73	72	73	69	70
7	78	77	74	74	74	76	73	70	71	72	70	73
8	73	76	74	73	73	71	73	74	73	72	68	64*
9	75	74	73	75	75	75	74	74	76	79	81	79
10	77	79	78	75	75	75	75	73	73	73	71	71
11	76	76	76	76	76	78	77	78	73	74	74	76
12	76	77	78	77	77	77	76	75	75	76	76	74
13	78	78	79	79	79	79	77	75	76	78	78	79
14	76	74	77	81	77	80	77	72	76	77	75	72
15	70	78	79	78	72	74	72	68	72	72	76	73
16	73	74	74	75	76	72	70	71	76	77	76	74
17	75	76	75	76	76	75	72	71	73	74	73	71
18	75	76	75	76	76	77	73	67	71	77	80	79
19	75	75	76	75	76	75	72	66	65	70	72	74
20	77	78	78	78	79	79	78	72	73	76	78	81
21	79	79	80	79	80	79	76	74	76	74	71	71
22	77	77	76	76	76	75	74	75	77	76	74	75
23	75	75	76	76	76	76	76	74	74	77	75	75
24	74	75	76	75	74	76	76	72	69	72	77	81
25	76	77	78	77	79	74	75	74	77	76	74	75
26	78	79	79	79	80	79	79	77	75	74	76	77
27	76	76	76	76	76	75	72	70	71	72	73	75
28	74	75	75	75	76	76	73	69	70	74	74	65
29	69	70	74	72	71	70	69	71	69	72	70	70
30	70	69	81	71	72	72	65	70	66	63*	69	73
31	70	70	70	71	73	74	74	74	71	68	66	70
Monthly mean	74·7	75·4	75·7	75·7	75·7	75·4	73·5	71·9	72·1	73·3	73·3	73·9
Normal	75·1	75·7	75·7	75·6	75·2	74·9	73·4	71·9	72·1	73·7	73·6	73·9

HORIZONTAL INTENSITY—Continued.

magnetometer of the Los Angeles Magnetic Observatory.

readings referred to standard temperature of magnet. Increasing numbers indicate increasing force.]

AUGUST, 1887.

13^h	14^h	15^h	16^h	17^h	18^h	19^h	20^h	21^h	22^h	23^h	Mid-night.	Daily mean.
79	79	70	56*	48*	45*	47*	47*	48*	51*	58*	57*	69·5 d
78	73	66	66	66	67	71	68	59*	61*	65	82	67·4
72	64	59*	58*	58*	63	72	62*	67	69	70	73	68·1
73	69	64	64	65	65	66	62*	65	66	69	72	69·4
73	70	67	69	70	69	69	69	65	72	72	77	72·1
70	71	70	67	65	67	69	72	77	75	70	81	72·1
72	70	72	67	64	69	[illegible]	69	68	78	68	71	71·6
64*	68	72	67	67	68	[illegible]	73	73	74	74	74	71·2
74	71	69	69	73	74	74	74	73	75	75	76	74·5
72	72	74	74	74	75	75	76	75	75	76	76	74·5
76	73	73	73	73	75	76	[illegible]	76	77	77	76	75·0
72	72	74	74	76	76	76	76	78	77	78	78	75·9
80	83*	88*	76	74	76	75	71	[illegible]	72	72	74	76·9
70	71	67	69	67	69	74	73	[illegible]	75	75	75	74·0
66	65	64	65	68	72	71	64	71	72	72	72	71·1
74	75	68	69	71	73	74	75	74	74	74	76	73·5
71	70	71	72	74	75	76	76	74	75	75	74	73·8
76	72	70	70	72	75	75	76	75	75	74	74	74·4
75	75	75	75	74	76	77	77	78	78	77	77	74·4
80	78	78	74	77	79	80	80	76	74	75	77	77·3
72	71	71	71	72	74	74	75	76	75	76	76	75·0
74	72	69	69	68	71	73	72	74	74	74	75	73·9
75	73	73	79	74	75	76	74	72	70	72	74	74·7
76	73	74	72	73	79	78	78	77	76	77	76	75·2
78	78	75	73	74	75	74	75	74	74	75	75	75·5
78	76	73	76	74	77	76	76	76	76	76	77	76·8
77	79	79	80*	79	76	76	77	77	76	75	75	75·6
57*	56*	58*	54*	58*	68	70	63*	58*	53*	65	77	67·2
68	55*	60*	63	60*	62*	58*	63*	68	64*	80	76	67·7
71	71	70	68	69	64	65	70	70	80	72	74	70·2
73	66	73	75	71	67	64	64	73	69	69	76	70·5
73·1	71·3	70·5	69·5	69·3	70·8	71·6	70·7	71·4	72·0	72·8	74·9	72·86
74·0	72·0	71·2	70·6	71·3	72·0	73·0	72·9	73·2	74·2	73·3	75·5	

DIFFERENTIAL MEASURES—

Hourly readings from the photographic traces of the bifilar

Local mean time. 200 divisions plus tabular quantity, one division = 0·000109 in parts of H. All

SEPTEMBER, 1887.

[For the explanation of these tables see pp. 53, 54.]

Day.	1^h	2^h	3^h	4^h	5^h	6^h	7^h	8^h	9^h	10^h	11^h	Noon.
1	73	74	77	76	73	72	69	68	71	67	68	71
2	71	71	72	73	69	71	69	65	60	64	64	62
3	74	72	74	73	72	70	68	66	68	70	72	70
4	72	71	71	72	71	71	69	67	67	67	67	67
5	71	72	73	73	73	72	70	67	68	71	74	75
6	71	72	73	73	72	72	69	68	66	69	72	72
7	72	73	73	74	74	74	73	72	70	72	71	72
8	74	75	75	75	75	74	72	73	75	75	75	74
9	77	77	76	75	74	75	73	71	72	74	75	75
10	78	71	79	80	73	80	77	76	74	71	70	69
11	73	74	72	74	76	72	74	71	70	70	70	71
12	72	74	74	73	74	72	71	70	69	72	73	73
13	73	74	74	74	72	71	68	68	66	68	68	64
14	74	75	76	77	77	75	74	71	74	76	76	70
15	69	70	71	71	73	72	71	65	62	68	70	71
16	70	69	70	74	72	72	66	65	65	68	66	71
17	76	69	70	71	72	72	69	66	66	68	70	69
18	72	70	71	72	73	73	71	70	69	69	68	68
19	76	75	75	74	74	74	72	72	74	73	72	69
20	74	74	74	74	74	74	71	69	69	70	71	71
21	74	73	83*	79	79	78	75	71	76	68	69	72
22	68	69	70	70	70	70	70	67	68	69	69	69
23	74	74	74	73	73	74	76	76	73	68	66	68
24	65	68	70	70	72	72	67	70	67	71	71	72
25	75	76	77	75	79	79	76	74	64	67	58*	57*
26	60*	57*	62*	70	66	64	62	59*	60	63	64	63
27	64	61*	68	66	73	65	62	62	65	68	63	54*
28	65	61*	63*	68	66	65	63	65	65	65	62	65
29	72	77	64	70	68	69	75	68	65	64	63	68
30	74	74	68	67	67	68	66	66	61	60	62	68
Monthly mean	71·8	71·4	72·3	72·9	72·5	72·1	70·3	68·6	68·0	68·8	68·6	68·7
Normal	72·2	72·7	72·6	72·9	72·5	72·1	70·3	68·9	68·0	68·8	69·0	69·6

HORIZONTAL INTENSITY—Continued.

magnetometer of the Los Angeles Magnetic Observatory.

readings referred to standard temperature of magnet. Increasing numbers indicate increasing force.]

SEPTEMBER, 1887.

13^h	14^h	15^h	16^h	17^h	18^h	19^h	20^h	21^h	22^h	23^h	Mid-night.	Daily mean.
70	61	62	65	65	68	71	65	73	70	70	79	69·9[d]
65	64	68	68	66	68	64	67	76	68	70	70	67·7
68	69	69	68	67	64	66	70	68	72	66	69	69·4
68	69	71	73	72	70	68	69	70	71	70	71	69·8
75	73	70	71	71	72	72	70	70	70	69	71	71·4
72	71	71	72	72	72	72	72	72	72	72	72	71·3
73	73	74	74	74	75	74	73	74	73	73	72	73·0
73	75	78	78	77	75	75	75	75	76	76	76	75·0
76	76	73	76	78	77	77	78	82*	65	72	73	74·9
74	71	74	72	68	69	71	73	73	72	73	73	73·4
67	59*	58*	62	68	72	70	71	70	69	73	71	69·9
72	72	70	72	71	72	72	72	72	73	76	76	72·4
65	67	71	73	74	75	75	76	75	74	75	75	71·4
71	69	72	76	76	73	76	73	73	68	68	70	73·3
68	71	71	69	61*	59*	63	61*	62	67	71	70	67·8
73	72	74	74	73	72	68	68	72	71	70	75	70·4
72	76	76	74	72	72	70	71	70	70	70	70	70·9
68	70	70	70	71	72	74	72	73	74	74	75	71·2
66	66	67	69	70	71	72	72	71	72	73	73	71·8
72	73	73	73	74	74	74	72	72	73	71	71	72·4
71	70	72	74	75	76	74	73	62	60*	69	64	72·4
69	69	70	70	71	72	72	71	71	71	71	72	69·9
66	66	62	60*	70	70	71	70	69	68	62	58*	69·2
72	72	71	71	74	73	73	74	74	73	72	74	71·2
54*	47*	37*	30*	13*	15*	48*	24*	62	51*	42*	56*	55·7
62	59*	52*	51*	54*	56*	62	54*	59*	62	64	60*	60·2
51*	52*	47*	46*	56*	54*	56*	59*	70	60*	65	68	60·6
64	66	64	62	67	69	68	67	66	75	68	68	65·7
67	65	65	64	63	67	65	69	65	62	69	70	67·2
69	68	69	65	63	63	69	68	67	69	68	68	67·0
68·4	67·7	67·4	67·4	67·5	67·9	69·4	68·3	70·3	69·0	69·4	70·3	69·54
69·6	69·8	70·3	70·6	70·8	71·3	70·6	71·2	70·3	70·4	70·3	71·7	

DIFFERENTIAL MEASURES—

Hourly readings from the photographic traces of the bifilar

[Local mean time. 200 divisions plus tabular quantity, one division = 0·000109 in parts of H. All

OCTOBER, 1887.

[For the explanation of these tables see pp. 53, 54.]

Day.	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	Noon.
1	71	71	70	69	70	69	69	64	62	65	[66]	[67]
2	68	67	68	68	70	71	72	68	63	60	65	66
3	70	70	70	72	70	72	74	73	70	66	64	65
4	72	72	72	73	73	72	73	70	66	64	66	69
5	70	72	73	76	74	75	76	74	70	67†	69	73
6	73	73	74	74	74	73	72	70	69	70	72	73
7	68	70	70	71	71	71	71	72	68	68	73	75
8	73	74	73	73	74	74	72	72	69	68	68	67
9	72	72	72	74	74	73	73	72	67	68	71	70
10	72	73	74	75	75	72	74	72	67	67	69	67
11	70	71	71	71	71	70	68	65	63	63	69	72
12	66	64	67	71	72	67	65	64	62	60	63	62
13	68	68	71	69	71	71	70	67	62	65	64	69
14	66	66	68	70	69	69	68	67	65	66	69	69
15	68	69	71	70	70	70	69	68	67	67	69	71
16	71	72	70	74	73	72	72	70	68	68	70	72
17	71	75	72	72	72	72	73	71	70	70	71	72
18	71	72	73	73	73	73	72	70	68	70	70	68
19	73	72	72	72	74	72	72	72	69	68	67	67
20	71	71	72	72	72	71	70	69	68	69	69	68
21	71	71	72	72	72	72	72	71	69	68	70	69
22	69	67	67	69	67	74	77	82*	77*	64	64	62
23	63	72	70	69	71	65	65	68	65	57	59	60
24	65	66	66	66	66	65	67	70	69	69	68	67
25	69	68	69	70	70	69	66	67	67	67	66	64
26	69	71	77	71	66	80*	69	60	55*	52*	61	61
27	69	69	67	64	68	66	63	63	62	59	61	61
28	65	65	65	66	66	66	64	64	64	62	61	62
29	66	66	66	66	67	67	67	66	66	64	62	62
30	58*	63	66	65	69	70	71	64	65	63	64	62
31	64	66	65	65	64	63	62	60	57*	57	58	61
Monthly mean	68·8	69·6	70·1	70·4	70·6	70·5	69·9	68·5	66·1	64·9	66·4	66·9
Normal	69·1	69·6	70·1	70·4	70·6	70·2	69·9	68·1	66·4	65·3	66·4	66·9

†Eye reading.

HORIZONTAL INTENSITY—Continued.

magnetometer of the Los Angeles Magnetic Observatory.

readings referred to standard temperature of magnet. Increasing numbers indicate increasing force.]

OCTOBER, 1887.

13^{h}	14^{h}	15^{h}	16^{h}	17^{h}	18^{h}	19^{h}	20^{h}	21^{h}	22^{h}	23^{h}	Mid-night.	Daily mean.
[67]	[68]	[68]	[69]	[69]	68	71	68	66	70	67	67	[67·9][d]
67	68	67	69	69	70	70	70	71	71	71	71	68·3
66	68	70	71	70	71	71	71	71	71	70	71	69·9
70	72	73	73	74	74	74	74	74	74	73	71	71·6
75	74	73	72	73	71	72	72	72	72	73	74	72·6
72	69	71	70	70	65	60	61	65	68	67	66	69·6
73	75	69	71	70	72	72	70	73	71	72	73	71·2
69	71	70	70	70	72	72	72	72	72	72	72	71·3
72	71	70	71	72	73	73	73	72	72	72	70	71·6
69	71	70	70	69	71	66	63	67	69	70	71	70·1
71	69	69	70	71	73	74	74	71	63	63	67	69·1
63	61	66	69	69	69	62	63	62	65	64	73	65·4
69	63	65	68	67	63	59*	67	63	66	65	67	66·5
67	64	65	67	64	67	67	69	68	68	68	68	67·3
70	69	70	69	69	71	70	71	72	72	71	70	69·7
74	73	71	70	72	70	75	73	75	70	72	77	71·8
72	72	68	67	68	68	68	66	69	69	69	71	70·3
68	70	72	71	71	72	72	70	70	72	72	71	71·0
69	72	73	72	72	72	72	71	71	71	70	70	71·0
69	69	70	71	72	70	70	70	71	71	71	70	70·2
70	72	73	75	77	76	76	70	69	63	63	66	70·8
62	69	62	77	67	67	69	64	67	66	66	64	68·3
56*	59	60	60	58*	59*	60	67	63	65	66	63	63·3
67	66	65	66	68	68	70	70	69	68	68	68	67·4
66	69	69	71	71	72	71	70	71	70	69	68	68·7
60	59	51*	54*	56*	58*	56*	59*	60	63	61	66	62·3
60	58*	58*	60	60*	62	61	65	63	62	65	65	63·0
62	62	63	64	64	65	65	64	64	64	65	65	64·0
65	66	68	69	68	66	66	66	68	69	66	66	66·2
63	63	60	62	66	66	65	65	65	64	64	64	64·5
62	62	64	64	65	65	64	65	66	65	65	65	63·1
67·3	67·5	67·2	68·4	68·4	68·6	68·2	68·2	68·4	68·3	68·1	68·7	68·33
67·6	67·9	68·1	68·9	69·5	69·3	68·9	68·5	68·4	68·3	68·1	68·7	

DIFFERENTIAL MEASURES—

Hourly readings from the photographic traces of the bifilar

[Local mean time. 200 divisions plus tabular quantity, one division = 0·000109 in parts of H. All

NOVEMBER, 1887.

[For the explanation of these tables see pp. 53, 54.]

Day.	1^h	2^h	3^h	4^h	5^h	6^h	7^h	8^h	9^h	10^h	11^h	Noon.
1	65	66	66	67	67	68	68	65	64	63	63	67
2	66	67	68	68	68	68	66	63	63	64	68	68
3	65	64	67	68	68	64	74	72	69	65	62	60
4	65	66	66	67	67	67	67	66	66	68	65	65
5	68	67	67	68	67	67	68	67	67	65	66	65
6	68	69	69	70	70	71	71	72	71	69	67	65
7	71	69	69	69	71	70	69	69	70	70	70	70
8	70	70	71	73	71	72	69	64	58	63	63	63
9	65	75	64	67	68	70	69	69	64	67	63	60
10	64	74	68	69	68	71	73	69	70	64	60	59
11	68	68	65	66	66	67	68	69	68	65	63	66
12	66	67	66	66	66	68	68	69	67	64	63	64
13	69	68	68	69	70	70	71	69	67	64	63	64
14	71	66	66	67	68	68	67	66	64	65	66	66
15	68	68	68	69	69	68	68	67	65	61	60	61
16	66	67	68	69	68	68	68	68	68	68	67	67
17	69	69	70	72	74	74	74	76	72	70	66	66
18	64	64	65	65	66	68	68	68	70	70	68	68
19	70	64	66	69	70	70	72	70	70	66	66	65
20	60	60	66	66	65	67	66	63	65	60	60	59
21	64	83*	59	57*	63	62	66	65	54*	50*	44*	42*
22	57	60	62	58*	62	62	63	63	62	59	59	63
23	59	60	62	63	63	63	64	63	64	65	63	60
24	66	64	64	65	65	66	65	65	66	66	64	64
25	63	66	65	64	65	65	66	66	63	62	61	65
26	64	65	66	66	66	66	66	66	66	65	65	68
27	68	68	68	69	68	67	67	69	70	68	66	68
28	66	66	65	67	68	68	69	70	69	69	65	66
29	65	68	69	68	66	64	67	62	65	66	62	64
30	65	66	69	63	65	66	67	66	67	64	60	64
Monthly mean	65·8	67·1	66·4	66·8	67·3	67·5	68·1	67·2	66·1	64·8	63·3	63·7
Normal	65·8	66·6	66·4	67·5	67·3	67·5	68·1	67·2	66·6	65·3	63·9	64·5

HORIZONTAL INTENSITY—Continued.

magnetometer of the Los Angeles Magnetic Observatory.

readings referred to standard temperature of magnet. Increasing numbers indicate increasing force.]

NOVEMBER, 1887.

13^h	14^h	15^h	16^h	17^h	18^h	19^h	20^h	21^h	22^h	23^h	Mid-night.	Daily mean.
66	64	65	65	66	66	64	63	62	64	63	65	65·1[d]
66	68	68	67	66	66	66	66	67	69	73	65	66·8
62	63	62	63	66	66	65	64	64	64	65	65	65·3
63	62	65	66	67	66	69	68	68	66	66	66	66·1
65	65	66	68	68	68	68	68	68	69	68	67	67·1
67	68	69	70	70	69	69	69	69	68	67	68	69·0
70	70	71	71	72	71	71	70	70	71	70	70	70·2
66	67	59	57	66	65	66	65	63	67	65	66	65·8
65	66	67	64	60	66	66	64	63	64	64	64	65·6
59	62	63	65	66	65	65	66	65	66	65	67	66·0
71	70	73	65	66	67	67	67	66	66	65	66	67·0
65	65	65	66	68	68	70	68	66	65	66	67	66·4
66	66	67	68	68	67	65	67	67	68	68	66	67·3
65	68	69	69	69	70	70	69	68	66	67	67	67·4
62	66	67	70	70	70	69	69	68	68	68	67	66·9
69	71	69	69	70	70	70	70	69	69	68	69	68·5
60	60	62	63	58	59	61	62	59	57	58	60	65·5
67	65	68	68	70	70	66	62	64	64	66	65	66·6
65	66	68	66	66	60	54*	55*	51*	52*	59	57	64·0
62	57	60	60	61	59	65	64	65	66	63	66	62·7
48*	44*	53*	49*	49*	55*	56*	57	55*	55*	59	66	56·5
56	57	57	55*	60	59	64	56*	58	67	62	55*	59·8
58	58	59	61	61	61	62	63	63	63	62	61	61·7
63	63	63	64	65	65	64	64	64	64	64	64	64·5
64	63	63	64	64	65	64	65	64	63	62	63	64·0
69	68	68	67	67	68	67	66	65	64	66	67	66·3
68	70	71	71	69	67	67	68	67	64	64	63	67·7
69	70	70	69	68	64	67	66	69	63	62	60	66·9
62	62	63	66	64	66	64	66	63	63	61	65	64·6
63	61	64	66	65	64	65	64	63	63	63	63	64·4
64·0	64·2	65·1	65·1	65·5	65·4	65·5	65·0	64·4	64·6	64·6	64·7	65·52
64·6	64·9	65·5	66·0	66·1	65·8	66·3	65·7	65·3	65·4	64·6	65·0	

DIFFERENTIAL MEASURES—

Hourly readings from the photographic traces of the bifilar

[Local mean time. 200 divisions plus tabular quantity, one division = 0·000109 in parts of H. All

DECEMBER, 1887.

[For the explanation of these tables see pp. 53, 54.]

Day.	1^h	2^h	3^h	4^h	5^h	6^h	7^h	8^h	9^h	10^h	11^h	Noon.
1	64	63	64	64	64	66	65	65	65	62	59	59
2	66	65	66	65	67	66	67	67	65	63	62	63
3	65	65	65	66	66	66	67	68	67	65	62	62
4	66	67	66	68	68	67	68	68	68	67	64	63
5	66	68	67	67	69	69	70	70	70	68	65	64
6	67	66	70	69	71	72	70	69	65	61	64	56
7	65	66	66	69	67	68	64	68	67	61	65	63
8	64	65	66	65	66	68	68	69	69	66	64	62
9	66	66	67	67	68	70	70	72	72	70	67	65
10	66	69	67	68	69	70	71	72	72	70	66	64
11	69	68	69	69	70	70	70	70	69	66	65	65
12	68	69	69	68	69	70	70	71	70	70	69	68
13	64	66	66	67	68	69	70	69	70	68	67	64
14	60	60	60	62	62	64	64	65	64	63	61	59
15	64	65	65	64	66	65	65	65	65	65	64	63
16	66	63	63	60	64	63	61	62	65	65	57	54
17	57	58	60	69	69	69	61	64	58	58	62	56
18	58	57	61	61	62	58	56*	60	60	63	59	59
19	61	62	61	66	61	66	65	63	64	61	60	58
20	63	62	63	62	63	65	72	64	62	61	60	53
21	63	62	65	63	61	61	69	59	67	54*	49*	50*
22	48*	56	54*	58	57	57	57*	58	56*	57	54	52
23	58	58	59	59	60	61	61	60	62	60	57	56
24	62	63	63	63	64	64	65	65	65	65	61	57
25	61	63	61	61	62	64	66	65	66	64	61	60
26	59	60	61	61	62	62	66	67	64	61	60	52
27	61	59	61	62	64	63	62	65	62	62	58	56
28	64	66	62	62	64	66	67	69	68	68	66	63
29	62	62	62	63	64	64	65	66	63	63	60	58
30	65	64	65	63	64	65	66	67	62	60	60	58
31	62	63	64	64	63	63	64	63	63	62	59	60
Monthly mean	62·9	63·4	63·8	64·4	65·0	65·5	65·9	66·0	65·3	63·5	61·5	59·4
Normal	63·4	63·4	64·1	64·4	65·0	65·5	66·5	66·0	65·6	63·8	61·9	59·7

HORIZONTAL INTENSITY—Continued.

magnetometer of the Los Angeles Magnetic Observatory.

readings referred to standard temperature of magnet. Increasing numbers indicate increasing force.]

DECEMBER, 1887.

13^h	14^h	15^h	16^h	17^h	18^h	19^h	20^h	21^h	22^h	23^h	Mid-night.	Daily mean.
61	61	64	66	68	66	67	66	66	66	66	67	$64·3^{d}$
63	63	65	68	68	67	66	66	64	64	65	66	65·3
64	64	69	69	68	68	66	66	66	66	66	66	65·9
62	64	66	68	68	69	68	67	66	66	67	67	66·6
64	67	70	70	70	71	70	66	68	69	67	66	68·0
58	60	60	64	64	65	63	64	60	59	62	64	64·3
61	57	61	63	66	66	62	65	64	64	62	63	64·3
63	61	62	63	64	66	68	68	67	67	64	66	65·4
63	62	63	64	66	67	66	65	65	64	65	66	66·5
65	65	65	66	68	69	69	68	67	70	68	68	68·0
64	63	64	66	68	69	69	68	69	69	68	68	67·7
66	66	67	71	73	71	64	71	65	66	61	68	68·3
60	59	59	58	58	55*	57	58	60	60	60	64	63·2
59	60	62	64	65	65	65	65	64	63	64	64	62·7
61	62	63	64	65	65	63	63	64	63	63	62	63·9
52	55	52*	54*	54*	55*	55	55	53	47*	54	55	57·7
54	50*	60	62	59	54*	54	51*	53	52*	55	57	58·4
56	56	52*	55	53*	58	57	59	60	56	56	66	58·3
58	57	58	60	62	63	62	61	63	62	61	66	61·7
55	59	60	61	61	62	61	58	56	65	59	66	61·4
48*	48*	45*	49*	47*	45*	44*	37*	43*	48*	52*	49*	53·3
52	54	55	58	60	59	59	59	58	58	58	58	56·3
56	58	61	62	63	63	62	60	60	60	60	62	59·9
56	57	59	61	63	64	64	61	63	63	64	64	62·3
60	60	59	50*	46*	53*	52*	51*	56	57	58	56	58·8
55	61	64	62	62	58	58	57	59	60	58	57	60·3
56	57	60	58	49*	60	60	60	60	65	61	59	60·0
60	57	60	62	60	57	56	54	55	62	67	61	62·3
58	58	61	63	65	65	61	62	64	65	63	63	62·5
56	62	63	65	66	66	63	61	60	60	63	61	62·7
60	59	64	65	63	65	65	64	64	63	63	64	62·9
58·9	59·4	61·1	62·3	62·3	62·8	61·8	61·2	61·4	61·9	61·9	62·9	62·68
59·3	60·1	62·3	63·5	64·8	64·8	62·8	62·8	62·0	63·3	62·3	63·3	

DIFFERENTIAL MEASURES—

Hourly readings from the photographic traces of the bifilar

[Local mean time. 200 divisions plus tabular quantity, one division = 0·000100 in parts of H. All

JANUARY, 1888.

[For the explanation of these tables see pp. 53, 54.]

Day.	1^h	2^h	3^h	4^h	5^h	6^h	7^h	8^h	9^h	10^h	11^h	Noon.
1	63	64	65	66	66	63	65	64	64	61	58	59
2	64	64	67	66	66	67	67	68	66	62	57	55
3	66	68	67	67	67	66	67	67	64	61	57	58
4	68	67	67	68	66	66	66	67	65	62	58	58
5	67	67	68	68	68	68	68	69	68	67	63	62
6	65	62	64	68	68	68	67	65	65	62	60	56
7	63	64	64	65	66	66	66	67	73*	71*	69*	68*
8	42*	46*	58	65	59	64	54*	52*	58	54	49	45*
9	55	56	56	58	58	57	58	59	58	57	54	51
10	59	59	59	59	60	62	62	62	61	59	54	50
11	57	57	58	60	59	60	62	64	64	62	54	52
12	55	57	59	60	59	62	64	64	64	63	60	58
13	47*	42*	48*	51*	57	57	66	72	67	62	45*	43*
14	53	54	55	54	58	58	60	59	58	55	38*	48
15	59	54	55	56	57	57	58	58	59	57	52	50
16	55	57	60	59	58	59	60	60	60	56	50	50
17	54	56	57	59	60	58	60	61	60	56	51	49
18	58	59	63	61	64	61	60	61	59	52	48	49
19	60	59	58	59	60	61	61	63	62	58	57	58
20	61	61	61	62	63	63	63	64	62	57	54	58
21	62	62	63	64	64	65	66	63	64	58	54	55
22	61	59	64	62	60	64	66	67	62	60	57	59
23	61	54	55	60	59	76*	71	56	51*	51	45*	54
24	56	56	55	60	62	60	61	63	62	57	58	62
25	59	60	61	64	65	61	62	60	58	56	54	53
26	57	59	61	60	62	62	64	66	66	64	60	57
27	60	61	61	62	62	66	65	65	56	61	54	61
28	63	60	60	60	62	63	65	67	67	67	67*	66*
29	61	62	62	64	64	64	65	68	68	65	64	64
30	62	62	64	65	64	65	65	66	66	64	65	67*
31	65	65	65	66	66	67	67	67	66	63	60	62
Monthly mean	59·3	59·1	60·6	61·9	62·2	63·1	63·6	63·7	62·7	60·0	55·7	56·0
Normal	60·3	60·2	61·1	62·2	62·2	62·7	63·9	64·1	62·8	59·6	56·2	55·7

HORIZONTAL INTENSITY—Continued.

magnetometer of the Los Angeles Magnetic Observatory.

readings referred to standard temperature of magnet. Increasing numbers indicate increasing force.]

JANUARY, 1888.

13h	14h	15h	16h	17h	18h	19h	20h	21h	22h	23h	Mid-night.	Daily mean.
58	62	65	66	65	64	63	63	65	64	65	65	63·5[d]
56	60	62	64	65	65	66	66	63	64	65	65	63·8
61	64	66	66	65	64	64	64	62	66	65	66	64·5
58	60	65	68	69	68	68	67	67	66	65	66	65·2
63	66	67	67	68	69	69	65	63	65	64	65	66·4
55	56	59	62	64	64	64	63	64	64	64	64	63·0
67*	63	66	63	52	51*	52	51*	50*	48*	45*	46*	60·7
45*	49*	51*	56	55	57	57	56	57	56	56	56	54·0
51	53	55	57	58	59	59	58	58	58	58	60	56·8
48	50	55	64	61	61	61	60	58	58	58	58	58·2
55	57	58	60	62	62	61	60	61	60	59	54	59·1
62	65	67	72*	70*	67	64	64	64	64	62	54	62·5
49	49*	46*	49*	48*	48*	54	52	50*	53	54	54	52·6
50	51	55	56	56	57	54	48*	49*	50*	53	59	53·7
52	56	58	60	58	58	58	56	54	56	60	54	56·3
54	59	61	62	63	62	62	59	51*	49*	47*	55	57·0
48	51	55	57	58	58	57	56	56	54	56	57	56·0
50	54	57	58	59	59	59	59	59	60	60	58	57·8
59	58	59	60	59	60	60	60	60	60	60	60	59·6
61	62	64	64	62	62	61	62	62	62	63	61	61·5
57	52	58	60	60	58	54	61	61	60	59	60	60·0
62	63	63	61	62	62	64	60	58	60	58	54	61·2
53	54	56	42*	39*	55	54	59	53	53	55	61	55·3
49	57	58	59	60	59	56	61	58	61	62	57	58·7
60	62	58	56	59	60	59	62	60	58	64	58	59·5
62	58	58	57	57	58	62	58	58	57	60	59	60·1
62	58	56	56	56	54	60	61	56	61	58	59	59·6
66*	63	61	56	56	58	61	61	62	63	61	59	62·2
66*	64	63	63	63	63	64	63	65	63	61	61	63·8
70*	69*	69	67	65	66	66	66	65	65	66	65	65·6
64	65	65	66	64	62	64	64	64	64	64	65	64 6
57·2	58·4	59·9	60·5	59·9	60·3	60·5	60·2	59·1	59·4	59·6	59·2	60·09
56·1	58·7	60·7	61·1	60·7	61·1	60·5	60·9	60·5	60·5	60·5	59·6	

DIFFERENTIAL MEASURES—

Hourly readings from the photographic traces of the bifilar

[Local mean time. 200 divisions plus tabular quantity, one division = 0·000109 in parts of H. All

FEBRUARY, 1888.

[For the explanation of these tables see pp. 53, 54.]

Day.	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	Noon.
1	65	65	66	65	65	65	65	65	62	59	59	62
2	65	64	64	65	65	65	64	64	65	66	66	66
3	66	66	66	66	67	68	69	69	66	61	58	56
4	64	65	67	66	66	66	66	66	65	61	57	56
5	66	64	64	65	71	69	69	72	70	65	61	61
6	66	65	66	67	67	67	68	69	69	66	62	61
7	67	67	67	66	67	68	68	70	73	73	68	66
8	65	67	67	68	68	66	67	69	71	71	70	67
9	58	62	64	64	67	67	64	65	66	67	67	68
10	65	64	63	66	63	68	66	66	63	61	61	57
11	60	64	67	62	65	66	65	68	66	66	66	58
12	61	67	63	64	66	66	64	64	68	68	63	64
13	65	66	64	64	67	67	66	68	69	71	72	72
14	65	65	66	67	67	66	67	66	66	66	67	67
15	63	63	64	65	66	66	66	66	67	67	68	67
16	65	67	67	68	70	68	67	69	66	67	64	61
17	62	64	64	64	65	69	66	67	67	63	67	67
18	62	63	70	74	68	68	67	67	68	68	66	65
19	59	62	64	64	67	66	66	68	65	63	63	60
20	60	62	68	66	67	65	64	62	63	60	66	69
21	60	59	62	64	67	64	63	63	64	63	58	64
22	67	64	70	68	64	63	62	57	57	58	59	64
23	63	64	64	67	65	64	64	62	61	59	58	62
24	61	61	63	64	63	63	66	63	64	66	67	67
25	61	62	61	64	65	67	64	65	65	66	67	67
26	66	63	66	65	65	65	65	61	62	62	63	66
27	65	65	66	66	67	67	64	62	62	65	66	68
28	66	68	66	69	68	68	66	63	61	62	64	64
29	73*	67	71	69	68	69	69	65	63	62	62	57
Monthly mean	63·8	64·4	65·5	65·9	66·4	66·4	65·8	65·6	65·3	64·6	64·0	63·8
Normal	63·5	64·4	65·5	65·9	66·4	66·4	65·8	65·6	65·3	64·6	64·0	63·8

HORIZONTAL INTENSITY—Continued.

magnetometer of the Los Angeles Magnetic Observatory.

readings referred to standard temperature of magnet. Increasing numbers indicate increasing force.]

FEBRUARY, 1888.

13^h	14^h	15^h	16^h	17^h	18^h	19^h	20^h	21^h	22^h	23^h	Mid-night.	Daily mean.
65	68	68	68	68	66	66	66	66	66	65	66	65·0d
68	67	66	68	68	67	67	67	67	66	66	66	65·9
57	59	61	61	63	62	62	63	63	63	65	64	63·4
57	56	60	61	62	61	56	60	59	66	56	60	61·6
60	61	62	64	66	67	66	66	66	66	65	64	65·4
61	61	62	64	66	67	68	67	67	67	66	67	65·7
69	65	66	63	68	68	68	67	67	67	67	67	67·6
66	65	65	67	67	67	65	66	69	52*	65	59	66·2
69	67	66	66	64	62	61	60	65	64	65	64	64·7
60	68	69	68	67	66	69	66	64	73	61	61	64·8
60	64	58	64	62	64	62	63	64	61	68	63	63·6
66	66	66	66	65	61	62	61	61	62	65	64	64·3
71	67	66	66	65	66	66	65	65	68	66	66	67·0
65	66	66	64	63	63	63	64	63	63	64	63	65·1
64	65	68	68	67	68	66	66	66	65	65	66	65·9
69	68	66	60	63	63	64	62	62	62	61	62	65·0
68	68	65	65	67	68	67	67	66	65	71	65	66·1
64	61	61	51*	62	55	57	61	66	58	63	60	63·5
70	65	58	52*	54*	62	61	63	61	61	59	63	62·3
68	62	61	62	61	64	61	63	61	61	60	65	63·4
67	66	62	64	60	58	57	56	59	60	60	61	61·7
64	61	54*	61	58	62	62	63	63	62	61	62	61·9
63	61	63	64	66	63	65	64	64	63	64	62	63·1
59	61	63	61	57	57	61	60	62	63	62	58	62·2
68	69	62	62	64	61	58	62	64	64	64	64	64·0
67	68	66	65	64	63	63	65	66	67	64	66	64·7
69	69	70	69	68	65	64	66	67	67	67	68	66·3
64	65	68	68	68	66	60	60	64	64	59	64	64·8
61	66	68	70	68	67	67	67	67	67	66	66	66·5
64·8	64·7	64·0	63·9	64·2	63·8	63·2	63·7	64·3	63·9	63·8	63·7	64·55
64·8	64·7	64·4	64·8	64·5	63·8	63·2	63·7	64·3	64·3	63·8	63·7	

DIFFERENTIAL MEASURES—

Hourly readings from the photographic traces of the bifilar

[Local mean time. 200 divisions plus tabular quantity, one division = 0·000109 in parts of H. All

MARCH, 1888.

[For the explanation of these tables see pp. 53, 54.]

Day.	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	Noon.
1	66	66	65	66	66	66	66	65	64	64	65	64
2	68	67	66	67	67	66	65	63	61	62	63	63
3	67	67	67	67	68	68	67	67	66	64	62	61
4	68	67	67	68	68	68	67	64	63	61	64	65
5	69	69	69	69	69	69	69	67	64	63	64	65
6	69	69	69	69	69	69	68	68	68	69	72*	73*
7	73	73	73	74	73	72	75	72	71	70	71	69
8	64	64	66	65	66	65	65	63	62	63	65	66
9	66	67	68	69	67	68	69	66	60	54*	66	61
10	65	66	65	65	63	73	68	63	60	61	65	65
11	66	66	65	65	66	65	66	64	62	64	61	60
12	66	68	67	67	67	66	66	63	60	60	59	60
13	68	69	68	69	68	69	67	63	61	60	60	63
14	67	69	69	70	70	69	68	63	60	58	58	57
15	69	69	71	75	78*	63	70	64	70	67	63	61
16	62	61	65	64	63	64	63	58	66	59	54	54
17	59	60	65	68	66	60	62	61	58	61	52*	55
18	61	60	60	65	64	63	64	61	62	64	59	59
19	62	64	64	66	64	65	65	66	65	62	55	59
20	65	64	64	65	65	63	62	60	59	58	60	58
21	66	67	70	70	69	68	67	65	63	62	58	60
22	64	65	66	66	68	67	66	63	62	64	62	58
23	65	67	67	67	68	68	66	64	62	67	67	63
24	68	68	70	69	68	72	69	68	65	61	60	62
25	72	71	71	70	71	70	70	68	66	66	65	66
26	69	69	69	70	70	69	68	64	64	65	63	63
27	69	69	70	71	70	71	70	69	68	65	62	60
28	70	70	71	76	71	71	72	71	69	67	63	57
29	69	69	68	68	68	69	68	67	68	67	65	64
30	68	69	69	69	69	68	67	65	66	67	66	66
31	65	65	68	67	67	69	67	66	68	65	62	60
Monthly mean	66·6	66·9	67·5	68·3	67·9	67·5	67·2	64·9	64·0	63·2	62·3	61·8
Normal	66·6	66·9	67·5	68·3	67·6	67·5	67·2	64·9	64·0	63·5	62·3	61·5

HORIZONTAL INTENSITY—Continued.

magnetometer of the Los Angeles Magnetic Observatory.

readings referred to standard temperature of magnet. Increasing numbers indicate increasing force.]

MARCH, 1888.

13h	14h	15h	16h	17h	18h	19h	20h	21h	22h	23h	Mid-night.	Daily mean.
60	64	64	63	66	67	65	65	66	66	65	64	64·9d
62	62	64	67	68	66	67	66	67	66	67	67	65·3
61	63	65	68	69	68	65	66	68	68	68	68	66·2
68	67	69	69	68	68	68	67	67	67	68	68	66·8
67	68	69	68	68	68	68	69	68	68	68	69	67·7
69	68	70	71	71	72	72	72	70	72	72	72	70·1
72	74*	71	71	66	64	67	57	55*	62	60	76	69·2
67	64	65	65	65	61	61	59	62	65	66	67	64·2
53*	60	64	64	65	63	63	64	60	62	65	64	63·7
63	62	63	63	62	65	64	63	66	63	63	67	64·3
62	63	64	66	67	68	68	68	68	67	66	66	65·1
61	64	64	65	67	68	68	68	68	67	68	67	65·2
64	66	60	63	66	68	67	67	67	68	68	69	65·8
61	63	62	62	64	67	67	66	67	67	69	70	65·1
64	64	52*	50*	58	54*	55*	50*	50*	50*	55*	61	61·8
44*	45*	50*	56*	46*	59	58	60	55*	54*	58	66	57·8
58	59	59	55*	55*	55*	58	59	57	62	55*	58	59·0
66	67	60	55*	59	62	62	63	60	59	63	64	61·7
59	62	63	60	57	61	65	61	62	62	64	64	62·4
59	62	64	62	64	65	63	65	64	66	64	65	62·8
59	61	62	65	66	65	66	66	66	65	64	64	64·8
60	60	62	65	65	66	66	67	66	66	69	66	64·5
64	66	68	68	66	65	65	65	72	64	67	67	66·2
66	69	72	72	70	69	69	68	67	67	68	69	67·8
69	72	73	72	69	69	68	69	69	68	69	69	69·3
64	66	70	72	71	70	70	70	70	70	70	70	68·2
62	66	75*	74	73	70	68	69	69	70	69	70	68·7
61	63	64	67	67	64	64	65	66	67	68	68	67·2
65	65	67	67	66	65	63	64	64	64	63	64	66·1
69	68	67	68	66	65	63	62	62	65	64	66	66·4
60	62	64	67	68	67	66	66	67	66	65	68	65·6
62·5	64·0	64·7	65·2	65·1	65·3	65·1	64·7	64·7	64·9	65·4	66·9	65·29
63·5	64·3	65·3	66·8	66·1	66·0	65·5	65·2	65·9	65·8	66·1	66·9	

DIFFERENTIAL MEASURES—

Hourly readings from the photographic traces of the bifilar.

[Local mean time. 200 divisions plus tabular quantity, one division = 0·000109 in parts of H. All

APRIL, 1888.

[For the explanation of these tables see pp. 53, 54.]

Day.	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	Noon.
1	69	70	70	69	69	69	67	66	66	64	61	61
2	66	66	66	67	68	68	69	66	66	65	63	62
3	64	66	66	68	66	66	66	64	70	70	70	68
4	69	71	67	66	69	63	68	67	68	67	64	49*
5	65	66	74	64	65	64	62	58	60	62	63	62
6	65	68	67	67	67	67	67	63	61	62	62	64
7	68	69	69	69	70	68	66	66	63	61	60	65
8	68	69	69	70	70	71	69	67	65	62	65	65
9	67	68	68	68	68	68	68	65	63	60	60	62
10	69	70	70	70	70	71	71	70	65	62	62	65
11	56*	61	73	70	68	62	60	60	58	54*	55*	55*
12	58*	65	63	63	69	69	64	62	58	53*	52*	51*
13	65	67	57*	61	64	68	66	65	70	52*	54*	51*
14	66	65	68	65	66	66	67	66	59	59	53*	49*
15	66	67	64	64	65	66	67	68	68	64	60	58
16	65	65	66	65	65	67	68	66	66	64	63	64
17	68	69	69	69	69	69	69	68	68	68	68	66
18	68	66	67	69	68	69	67	66	65	64	63	63
19	70	71	72	72	71	73	71	71	68	67	70	74
20	70	70	70	73	71	72	69	68	71	70	70	69
21	70	70	70	70	71	71	66	63	63	65	65	67
22	70	71	71	71	72	71	68	67	69	70	69	68
23	71	72	72	72	73	73	71	68	67	66	67	68
24	74	71	74	74	73	74	72	70	66	67	66	68
25	69	69	69	68	69	70	69	66	64	62	64	64
26	69	70	69	71	71	72	72	70	66	64	65	66
27	70	70	70	70	70	71	69	66	63	64	66	68
28	72	73	73	72	72	79*	80*	74	72	68	67	68
29	70	70	71	70	71	71	72	70	69	69	70	72
30	70	70	70	72	70	71	70	69	69	71	71	71
Monthly mean	67·6	68·5	68·8	68·6	69·0	69·3	68·3	66·5	65·5	63·9	63·6	63·4
Normal	68·3	68·5	69·2	68·6	69·0	68·9	67·9	66·5	65·5	65·2	65·2	65·9

HORIZONTAL INTENSITY—Continued.

magnetometer of the Los Angeles Magnetic Observatory.

readings referred to standard temperature of magnet. Increasing numbers indicate increasing force.]

APRIL, 1888.

13^h	14^h	15^h	16^h	17^h	18^h	19^h	20^h	21^h	22^h	23^h	Mid-night.	Daily mean.
63	65	66	69	70	70	69	68	67	71	67	67	67·2[d]
71	69	72	73	71	73	53*	45*	46*	45*	57*	64	63·8
65	61	59	65	66	57*	60	57*	60	75	69	65	65·1
58	60	65	66	65	64	65	64	65	66	62	71	65·0
60	60	64	65	62	59	58	63	66	67	66	64	63·3
65	67	66	65	66	67	67	67	68	67	67	68	65·8
66	67	66	66	65	67	67	66	66	66	67	67	66·2
66	66	67	65	66	67	66	67	67	68	66	67	67·0
64	64	66	68	70	69	68	69	69	69	69	69	66·6
67	69	71	72	72	72	67	70	67	70	66	63	68·4
54*	57*	51*	42*	41*	54*	50*	54*	57*	60*	67	65	57·7
54*	57*	52*	56*	61	63	63	64	63	64	62	61	60·3
57*	56*	57*	62	61	58*	59	60	63	66	64	63	61·1
59	63	63	69	59	61	60	60	61	68	64	62	62·4
58	62	66	64	62	61	63	63	64	63	66	65	63·9
65	65	66	68	65	66	67	68	66	68	68	67	66·0
66	64	67	68	70	68	64	64	62	66	64	65	66·6
64	64	66	67	65	65	66	66	68	68	68	68	66·3
75	76*	73	74	73	70	69	65	66	67	67	67	70·5
72	72	71	72	68	68	69	70	70	70	69	69	70·1
69	69	69	69	69	70	70	70	69	69	68	70	68·4
68	68	68	69	69	69	70	71	71	70	71	71	69·7
69	71	72	72	71	72	73	75	72	71	71	73	70·9
73	69	64	61	68	69	68	65	65	67	67	70	69·0
66	65	68	69	67	67	68	66	64	62	62	67	66·4
68	69	71	71	69	68	67	68	67	68	69	69	68·7
69	70	71	73	72	70	69	69	69	70	71	71	69·2
70	71	71	71	68	66	66	68	68	70	69	68	70·7
78*	77*	74	75	77*	76	70	74	75	76	72	70	72·5
72	74	73	72	71	71	68	71	67	70	69	69	70·5
65·7	66·2	66·5	67·3	66·6	66·6	65·3	65·6	65·6	67·2	66·8	67·2	66·65
66·5	66·6	68·0	68·6	67·2	67·7	66·3	67·1	66·6	68·0	67·2	67·2	

DIFFERENTIAL MEASURES—

Hourly readings from the photographic traces of the bifilar

[Local mean time. 200 divisions plus tabular quantity, one division = 0·000109 in parts of H. All

MAY, 1888.

[For the explanation of these tables see pp. 53, 54.]

Day.	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	Noon.
1	58*	65	69	66	66	66	64	63	64	65	64	66
2	68	70	70	69	70	71	69	69	68	65	63	62
3	68	72	68	68	68	67	66	65	65	64	63	64
4	70	70	69	70	70	70	69	68	68	68	67	66
5	68	69	69	68	68	69	68	67	68	69	69	70
6	70	70	70	70	70	70	68	66	67	68	70	70
7	59*	69	63	64	64	60	62	63	64	62	57*	60
8	68	67	64	66	63	65	65	63	66	64	63	60
9	67	66	67	66	67	66	69	65	63	59	56*	58
10	67	68	68	68	70	66	66	62	62	63	67	60
11	69	69	69	67	67	66	70	68	67	64	65	66
12	72	70	68	69	69	71	70	68	61	56*	63	65
13	70	68	67	67	68	70	71	71	70	66	65	64
14	68	69	70	69	70	69	68	68	68	68	68	70
15	72	71	72	71	71	71	70	69	73	74	76*	69
16	70	69	70	69	70	71	72	71	67	67	67	68
17	69	67	69	70	70	71	70	70	69	66	67	69
18	72	73	73	73	73	73	72	70	71	73	72	74
19	69	69	69	69	69	68	66	65	68	72	71	72
20	71	78*	81*	79*	78*	79*	81*	68	75	79*	80*	74
21	55*	56*	57*	62	67	73	64	61	62	65	64	62
22	68	65	66	64	64	64	63	64	66	66	65	66
23	66	66	68	66	67	66	65	67	72	78*	76*	68
24	62	62	65	64	64	62	59	57*	60	64	68	70
25	67	67	68	67	69	66	65	64	66	68	69	70
26	74	72	78*	77	71	72	65	72	68	69	68	65
27	70	70	66	68	68	67	65	66	68	70	68	65
28	70	69	67	69	73	68	69	66	65	64	63	65
29	76	69	70	69	69	70	65	64	63	64	65	62
30	68	73	71	67	68	68	66	65	65	64	65	66
31	70	71	70	70	69	70	68	67	68	70	69	68
Monthly mean	68·1	68·7	68·7	68·4	68·7	68·5	67·4	66·2	66·7	66·9	66·9	66·3
Normal	69·3	68·8	68·4	68·1	68·4	68·2	67·0	66·5	66·7	66·5	66·5	66·3

HORIZONTAL INTENSITY—Continued.

magnetometer of the Los Angeles Magnetic Observatory.

readings referred to standard temperature of magnet. Increasing numbers indicate increasing force.]

MAY, 1888.

13h	14h	15h	16h	17h	18h	19h	20h	21h	22h	23h	Mid-night.	Daily mean.
70	68	65	66	64	64	66	64	71	62	64	66	65·2d
65	62	64	64	66	63	64	66	65	67	65	65	66·3
67	65	66	66	68	67	66	68	67	66	66	73	66·8
65	65	65	65	66	68	68	68	68	68	69	68	67·8
69	68	68	68	68	69	69	69	68	69	69	70	68·6
71	71	71	74*	77*	77*	79*	81*	80*	70	68	56*	71·0
55*	62	60	59	53*	55*	51*	53*	55*	60	67	62	60·0
64	67	66	61	61	62	55*	71	61	67	68	69	64·4
61	63	63	64	64	64	65	67	60	62	65	67	63·9
70	74	71	66	64	61	59	58	60	63	74	67	65·6
69	70	67	67	66	65	63	60	63	70	71	67	66·9
67	72	68	65	63	65	64	66	67	66	66	67	66·6
64	64	65	65	64	65	66	66	66	67	68	68	66·9
69	66	66	64	66	67	66	67	68	68	69	69	68·0
79*	79*	74	71	68	69	68	70	67	68	70	68	71·2
67	66	66	65	66	67	68	69	69	69	69	69	68·4
69	69	67	68	69	69	70	69	70	71	71	72	69·2
73	69	64	62	64	66	68	63	55*	65	66	68	68·8
70	67	67	65	64	66	68	68	68	68	69	70	68·2
79*	68	63	56	44*	49*	28*	32*	24*	32*	37*	51*	61·9
63	60	56*	51*	59	61	61	61	61	62	63	66	61·3
66	63	61	61	63	65	66	66	65	66	65	66	64·8
62	62	60	52*	55*	51*	53*	51*	60	60	60	61	63·0
68	68	65	62	60	59	58	61	64	64	65	66	63·2
72	68	67	65	62	62	66	66	67	66	70	71	67·0
64	65	66	63	59	64	66	65	65	64	67	72	68·0
63	63	63	66	66	66	66	66	65	65	67	69	66·5
67	68	69	68	65	66	67	67	66	65	68	67	67·1
66	70	67	67	65	66	66	66	66	68	68	69	67·1
70	71	69	67	65	66	66	68	68	67	70	68	67·5
67	66	66	67	68	69	69	68	67	68	69	69	68·5
67·5	67·0	65·6	64·2	63·6	64·3	63·7	64·5	64·1	64·9	66·5	67·0	66·44
67·1	66·6	66·0	64·7	64·6	65·2	65·7	66·1	65·6	66·0	67·5	67·9	

DIFFERENTIAL MEASURES—

Hourly readings from the photographic traces of the bifilar

[Local mean time. 200 divisions plus tabular quantity, one division = 0·000109 in parts of H. All

JUNE, 1888.

[For the explanation of these tables see pp. 53, 54.]

Day.	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	Noon.
1	69	70	70	69	69	70	67	67	70	74	73	74
2	69	70	70	70	70	69	69	68	71	75	76	75
3	71	64	72	69	68	68	74	69	67	64	52*	64
4	69	65	64	64	64	63	60	61	63	62	67	67
5	67	67	67	67	67	66	66	64	67	66	66	68
6	69	67	67	70	68	68	64	64	65	65	64	64
7	67	67	67	68	67	68	68	64	60	61	62	65
8	69	70	70	67	68	67	67	64	62	60	63	67
9	68	68	69	68	69	68	65	61	64	65	66	67
10	70	71	72	74	75	75	72	70	69	66	68	68
11	67	68	68	68	71	71	71	69	70	73	75	76
12	68	68	69	68	70	71	68	67	65	[66]	[67]	[68]
13	67	69	68	68	67	68	68	64	64	70	74	75
14	68	68	68	68	70	71	71	69	71	73	71	68
15	70	72	72	73	74	72	71	73	66	76	73	71
16	70	72	70	70	68	71	68	67	67	66	67	66
17	69	69	69	69	70	70	67	66	69	74	73	70
18	68	69	69	70	70	70	68	70	71	69	66	67
19	71	72	73	75	75	75	71	70	68	68	68	67
20	69	69	68	68	69	69	65	65	65	69	74	76
21	72	72	72	73	73	71	70	69	70	69	71	70
22	72	69	71	74	72	78	75	75	70	73	73	72
23	72	66	68	66	66	67	64	66	66	65	65	70
24	70	70	70	70	72	71	69	68	68	70	69	68
25	68	69	70	68	68	68	67	68	68	67	64	62
26	66	65	68	68	67	66	65	66	66	[69]	[71]	73
27	68	68	68	67	69	69	66	68	67	70	72	71
28	70	67	68	68	69	68	68	66	64	66	69	72
29	70	69	69	68	69	71	69	65	62	62	62	61
30	70	70	69	70	70	71	72	71	67	67	71	75
Monthly mean	69·1	68·7	69·2	69·2	69·5	69·7	68·2	67·1	66·7	68·0	68·4	69·2
Normal	69·1	68·7	69·2	69·2	69·5	69·7	68·2	67·1	66·7	68·0	69·0	69·2

HORIZONTAL INTENSITY—Continued.

magnetometer of the Los Angeles Magnetic Observatory.

readings referred to standard temperature of magnet. Increasing numbers indicate increasing force.]

JUNE, 1888.

13^h	14^h	15^h	16^h	17^h	18^h	19^h	20^h	21^h	22^h	23^h	Mid-night.	Daily mean.
71	68	67	66	67	68	68	69	69	69	69	70	69·3[d]
74	73	72	76*	78*	73	72	72	71	65	59	62	70·8
65	54*	64	63	58	58	52*	57	59	59	58*	66	63·1
60	53*	55*	59	60	60	64	62	64	65	74	66	63·0
68	70	66	57	58	54*	63	58	65	64	67	74	65·1
68	66	64	64	66	62	64	66	65	68	67	66	65·9
65	65	64	63	60	66	66	64	66	67	70	69	65·4
68	66	64	64	63	64	65	65	67	67	68	69	66·0
68	70	71	69	68	67	67	69	72	67	70	69	67·7
68	67	63	64	66	66	67	66	66	67	67	66	68·5
75	74	71	71	70	70	69	66	63	63	67	68	69·8
[67]	[66]	[66]	[64]	64	62	64	66	66	66	67	67	[66·7]
74	72	68	68	67	68	68	67	68	68	68	67	68·5
67	68	66	66	67	68	69	68	74	68	66	68	68·8
71	71	68	65	62	61	62	63	61	66	67	69	68·7
65	63	63	65	65	68	68	68	68	67	68	69	67·5
67	65	64	64	64	66	67	67	69	68	68	68	68·0
63	64	66	70	70	70	71	71	71	71	70	71	69·0
66	64	65	63	64	67	68	68	67	68	69	68	68·8
76	69	69	67	65	68	68	69	70	72	72	72	69·3
67	68	68	68	65	63	63	68	65	72	71	74	69·3
67	62	64	63	63	48*	57	64	66	69	69	66	68·0
69	68	64	61	58	63	61	64	66	67	67	69	65·8
64	67	65	64	63	62	65	66	69	68	70	69	67·8
64	66	65	65	63	64	65	65	67	64	64	64	66·0
72	71	69	66	64	61	63	64	66	64	67	67	[66·8]
70	71	69	68	67	69	68	69	66	66	65	69	68·3
73	73	71	69	67	67	67	69	69	70	69	71	68·8
63	63	63	65	64	66	68	68	68	66	68	69	66·2
70	72	74	53*	57	58	64	58	58	62	64	68	66·7
68·2	67·0	66·3	65·0	64·4	64·2	65·4	65·9	66·7	66·8	67·5	68·3	67·45
68·2	67·9	66·7	65·0	64·0	65·2	65·9	65·9	66·7	66·8	67·8	68·3	

DIFFERENTIAL MEASURES—

Hourly readings from the photographic traces of the bifilar

[Local mean time. 200 divisions plus tabular quantity, one division=0·000109 in parts of H. All

JULY, 1888.

[For the explanation of these tables see pp. 53, 54.]

Day.	1^h	2^h	3^h	4^h	5^h	6^h	7^h	8^h	9^h	10^h	11^h	Noon.
1	67	69	71	76	69	72	68	69	64	66	66	66
2	67	68	68	66	66	64	61	60	61	60	63	69
3	67	66	67	67	66	68	67	66	65	63	64	63
4	68	68	67	65	66	68	68	68	70	70	69	67
5	68	68	68	66	69	70	70	68	66	65	64	67
6	70	70	70	70	71	70	69	65	66	67	66	66
7	72	72	72	73	72	74	72	71	71	74	73	75
8	67	69	71	68	67	66	67	66	63	61	66	69
9	71	66	65	65	66	69	70	67	67	67	73	77*
10	68	69	67	67	69	68	66	62	62	64	68	70
11	69	69	69	69	69	71	70	67	64	65	65	65
12	67	68	68	68	69	71	70	66	65	62	62	64
13	67	67	68	68	69	70	70	67	64	64	67	70
14	69	70	70	70	70	71	69	66	65	66	67	68
15	70	70	71	68	71	71	69	69	70	72	74	71
16	69	69	68	68	69	68	66	67	64	65	65	63
17	67	65	64	64	65	66	62	61	60	62	68	64
18	66	65	65	64	65	65	65	68	68	66	65	66
19	66	66	68	69	71	70	70	67	66	64	63	65
20	70	75	72	71	73	73	73	70	71	69	65	68
21	66	62	68	62	65	65	63	60	62	62	63	62
22	68	60	62	63	64	62	61	60	60	61	63	65
23	67	65	65	66	67	64	63	60	60	68	65	64
24	62	64	65	64	66	65	65	63	58	59	65	67
25	65	67	68	67	67	68	67	65	65	65	66	69
26	66	66	67	67	66	67	66	62	61	63	65	65
27	66	66	67	68	68	69	67	64	63	61	62	63
28	68	73	76	69	72	70	67	67	69	70	67	63
29	66	69	66	67	66	65	63	63	64	69	71	72
30	67	67	68	67	67	67	66	63	62	63	68	69
31	70	68	68	68	68	67	64	62	63	66	67	66
Monthly mean	67·6	67·6	68·0	67·4	68·0	68·2	66·9	65·1	64·5	65·1	66·3	67·0
Normal	67·6	67·6	68·0	67·4	68·0	68·2	66·9	65·1	64·5	65·1	66·3	66·7

HORIZONTAL INTENSITY—Continued.

magnetometer of the Los Angeles Magnetic Observatory.

readings referred to standard temperature of magnet. Increasing numbers indicate increasing force.]

JULY, 1888.

13^h	14^h	15^h	16^h	17^h	18^h	19^h	20^h	21^h	22^h	23^h	Mid-night.	Daily mean.
60	64	63	66	61	61	52*	59	63	67	60	66	65·2[d]
69	67	63	59	59	62	56	63	67	67	65	65	64·0
63	64	62	62	62	64	64	66	67	67	67	66	65·1
65	66	65	67	62	65	66	67	66	68	68	68	67·0
67	66	66	66	64	65	66	67	67	68	69	69	67·0
66	68	70	67	64	67	69	70	71	72	72	71	68·6
75	73	70	66	64	60	62	67	69	64	66	68	69·8
65	63	59	60	60	64	65	65	68	67	65	68	65·4
75	72	68	64	64	63	65	65	68	67	67	68	67·9
73	75	71	67	64	64	66	66	67	68	68	68	67·4
67	70	68	69	66	66	67	67	67	67	67	66	67·5
67	70	68	68	65	65	65	65	64	65	66	66	66·4
72	73	71	69	65	65	66	68	68	67	67	68	67·9
66	65	65	64	66	66	67	67	67	68	69	69	67·5
69	65	62	64	64	66	67	67	67	66	67	68	68·3
56*	65	66	65	58	63	63	62	62	57	59	63	64·2
59	59	58	58	56	61	63	64	64	64	65	66	62·7
66	67	65	63	63	64	67	63	64	64	66	66	65·2
70	71	68	66	64	64	65	65	59	60	68	70	66·5
75	64	63	55	55	57	59	62	65	64	65	65	66·6
62	62	65	65	62	62	64	64	64	66	67	62	63·5
60	61	62	59	60	58	58	64	64	63	67	74	62·5
64	62	62	61	60	58	60	64	66	65	65	69	63·8
69	67	63	62	60	60	62	64	64	64	64	65	63·6
71	70	66	65	62	64	65	64	65	67	66	66	66·3
63	66	66	64	63	64	65	65	65	65	66	66	65·0
64	64	64	64	62	66	67	69	67	67	64	72	65·6
73	67	68	55	54	60	64	63	59	70	64	60	66·2
71	69	63	61	62	65	63	64	63	70	65	68	66·0
69	70	68	64	62	66	67	67	67	68	69	68	66·6
66	64	64	63	66	65	64	65	64	65	67	67	65·7
67·0	66·7	65·2	63·5	61·9	63·2	63·8	65·1	65·4	66·0	66·1	67·1	65·96
67·4	66·7	65·2	63·5	61·9	63·2	64·2	65·1	65·4	66·0	66·1	67·1	

DIFFERENTIAL MEASURES—

Hourly readings from the photographic traces of the bifilar

[Local mean time. 200 divisions plus tabular quantity, one division = 0·000109 in parts of H. All

AUGUST, 1888.

[For the explanation of these tables see pp. 53, 54.]

Day.	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	Noon.
1	66	66	67	66	68	69	69	67	66	65	64	67
2	68	68	69	70	72	74	74*	70*	67	68	67	68
3	65	69	69	75*	70	69	65	61	68	65	60	54*
4	61	62	61	65	61	61	60	61	60	64	63	67
5	66	64	66	65	65	64	64	60	60	60	60	65
6	65	66	66	65	66	67	65	60	55	54	58	62
7	65	65	65	66	66	66	65	61	60	59	62	65
8	67	66	66	66	65	66	67	68	68	67	66	68
9	67	66	66	65	66	66	65	60	59	60	64	65
10	71	70	71	70	70	70	67	64	65	65	64	63
11	67	67	68	68	70	71	68	66	66	64	65	63
12	60	58	63	63	66	62	61	57	59	59	59	60
13	64	65	66	66	66	67	65	62	59	57	58	60
14	67	67	67	66	67	68	65	64	64	65	66	68
15	66	66	67	68	68	67	64	61	64	69	74*	78*
16	55*	60	72	62	68	61	59	54	51*	56	60	64
17	62	72	65	67	58	64	64	58	58	58	59	63
18	62	62	62	62	63	60	58	55	55	57	59	56
19	64	58	62	60	61	62	60	58	58	56	56	57
20	60	66	61	62	62	60	58	57	58	57	58	57
21	63	64	63	64	64	63	60	56	58	59	59	59
22	61	63	63	62	64	63	58	54	54	57	59	60
23	63	63	65	64	64	64	61	58	58	62	66	68
24	65	65	65	65	66	66	62	58	59	64	68	69
25	67	67	66	67	66	65	62	58	55	58	63	68
26	70	70	69	70	68	68	65	62	60	60	64	68
27	67	68	67	66	65	67	65	60	58	59	60	62
28	68	68	68	69	69	68	65	61	60	57	61	66
29	66	66	67	67	67	67	64	61	61	65	70	72
30	68	69	69	70	70	71	70	70*	68	74*	74*	74*
31	67	66	62	63	65	64	64	61	58	57	60	62
Monthly mean	64·9	65·5	65·9	65·9	66·0	65·8	63·8	60·7	60·3	61·2	62·8	64·5
Normal	65·3	65·5	65·9	65·6	66·0	65·8	63·5	60·1	60·6	60·8	62·0	64·0

HORIZONTAL INTENSITY—Continued.

magnetometer of the Los Angeles Magnetic Observatory.

readings referred to standard temperature of magnet. Increasing numbers indicate increasing force.]

AUGUST, 1888.

13^h	14^h	15^h	16^h	17^h	18^h	19^h	20^h	21^h	22^h	23^h	Mid-night.	Daily mean.
66	65	64	62	63	66	66	66	66	66	67	67	66·0d
68	71	68	58	63	62	65	64	64	63	62	66	67·0
51*	51*	50*	47*	47*	48*	47*	50*	50*	53*	72	61	59·0
67	65	65	63	62	60	60	63	63	63	63	64	62·7
67	65	62	58	61	62	62	62	63	65	65	64	63·1
64	64	61	63	63	62	62	65	65	64	64	64	62·9
68	68	67	65	64	63	61	62	63	63	64	65	64·1
70	69	66	66	62	63	64	65	65	65	66	66	66·1
67	66	65	66	65	65	66	66	66	67	67	70	65·2
66	65	63	63	63	64	66	66	66	67	67	67	66·4
63	62	64	57	62	63	63	65	68	63	58	57	64·5
61	62	62	61	62	62	64	64	63	62	61	63	61·4
65	63	61	61	59	63	65	63	65	64	66	66	63·2
74	76*	72	69	67	65	64	65	66	66	66	65	67·0
78*	76*	75*	71	73*	73*	70	52*	48*	58	74*	59	67·5
59	56*	59	59	52*	58	57	56	58	65	56	64	59·2
61	56*	58	47*	57	61	60	56	60	60	55*	65	60·2
59	60	58	56	56	56	58	59	60	64	61	60	59·1
58	58	60	60	60	62	59	62	57	59	55*	66	59·5
56*	58	59	56	55	60	60	63	64	63	62	63	59·8
62	63	61	61	60	62	62	62	60	59	67	62	61·4
63	62	61	59	58	58	58	60	61	62	62	63	60·2
67	68	67	66	64	61	62	64	65	64	64	65	63·9
69	67	66	65	63	64	64	66	66	65	65	66	64·9
70	72	71	69	68	67	67	68	68	68	68	68	66·1
70	71	70	67	67	66	66	66	66	66	68	68	66·9
67	68	66	64	64	64	66	66	64	64	67	68	64·7
68	68	67	67	65	66	66	65	65	63	63	64	65·3
70	68	66	67	67	68	68	68	68	68	68	68	67·0
74	74	66	66	65	61	62	66	66	67	62	62	68·3
64	64	65	64	62	63	61	62	63	63	62	64	62·8
65·5	65·2	64·0	62·0	61·9	62·5	62·6	62·8	63·0	63·5	64·1	64·5	63·72
66·0	65·6	64·1	63·1	62·4	62·7	63·1	63·6	63·9	63·9	64·4	64·5	

DIFFERENTIAL MEASURES—

Hourly readings from the photographic traces of the bifilar

[Local mean time. 200 divisions plus tabular quantity, one division = 0·000109 in parts of H. All

SEPTEMBER, 1888.

[For the explanation of these tables see pp. 53, 54.]

Day.	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	Noon.
1	64	63	65	64	65	64	64	61	61	61	62	59
2	64	65	64	63	66	62	60	59	58	62	62	61
3	65	64	64	65	64	64	59	56	56	59	63	66
4	64	64	65	65	65	65	61	57	58	61	64	67
5	66	66	66	65	66	65	63	61	57	61	66	67
6	67	68	67	67	67	66	64	64	63	63	65	65
7	71	68	69	70	71	71	66	64	66	67	70*	71*
8	62	64	63	64	65	66	67	66	66	66	65	61
9	63	65	65	66	65	63	64	62	62	61	62	62
10	64	65	65	65	65	64	59	57	57	68	60	60
11	64	64	65	65	64	63	59	55	57	61	64	66
12	62	65	65	62	64	65	64	59	59	58	59	57
13	66	53*	64	59	62	60	57	56	52	52	51	58
14	65	66	63	64	64	63	60	57	53	56	57	56
15	64	59	60	61	62	66	61	55	56	58	58	57
16	55	58	62	60	58	59	58	54	51	52	55	58
17	60	62	62	62	61	60	60	56	55	57	58	58
18	60	58	60	64	64	63	61	61	61	60	58	56
19	61	63	63	66	65	62	58	58	60	60	58	57
20	56	55	59	59	62	61	58	55	55	58	57	57
21	60	62	62	62	63	63	60	54	52	54	54	58
22	62	62	63	64	64	62	58	57	57	58	60	63
23	65	64	64	65	64	63	60	56	54	55	55	59
24	64	64	65	66	65	64	62	60	61	63	64	64
25	62	64	66	63	67	63	58	58	58	57	56	55
26	61	60	59	64	63	62	59	55	55	57	56	54
27	52*	56	57	58	60	59	57	58	57	58	58	57
28	61	60	59	61	60	62	60	60	61	62	60	56
29	59	60	61	61	61	60	54	54	55	58	56	60
30	61	60	61	62	62	61	60	56	54	55	56	58
Monthly mean	62·3	62·2	63·1	63·4	63·8	63·0	60·4	58·1	57·6	59·3	59·6	60·1
Normal	62·7	62·6	63·1	63·4	63·8	63·0	60·4	58·1	57·6	59·3	59·3	59·7

HORIZONTAL INTENSITY—Continued.

magnetometer of the Los Angeles Magnetic Observatory.

readings referred to standard temperature of magnet. Increasing numbers indicate increasing force.]

SEPTEMBER, 1888.

13^h	14^h	15^h	16^h	17^h	18^h	19^h	20^h	21^h	22^h	23^h	Mid-night.	Daily mean.
64	69	65	66	63	62	60	61	62	62	61	65	63·0^{d}
64	64	58	58	62	57	60	62	64	63	64	65	62·0
65	65	64	63	63	62	63	63	63	64	64	64	62·8
69	68	67	64	65	65	65	65	65	66	65	66	64·4
69	70	69	67	66	65	67	67	67	68	68	67	65·8
63	62	63	64	66	67	68	69	69	69	70*	70	66·1
71*	66	68	68	67	66	66	64	60	53	62	63	66·6
58	61	62	64	63	64	63	63	62	61	64	63	63·5
62	64	64	65	64	62	61	62	62	62	64	64	63·2
60	60	62	64	64	64	64	66	64	64	64	64	62·9
66	65	66	65	67	70	71*	68	63	61	61	61	63·8
62	66	65	61	51*	60	60	61	63	64	58	59	61·2
59	59	56	49*	58	60	61	62	61	58	57	64	58·1
55	59	59	61	46*	46*	53	55	61	58	61	62	58·3
56	60	57	57	56	56	60	59	61	58	61	60	59·1
59	59	58	58	56	58	59	59	59	60	64	63	58·0
60	60	58	58	59	60	59	58	60	60	60	60	59·3
53	49*	48*	44*	44*	47*	46*	49*	50*	56	56	58	55·2
56	55	50	45*	45*	49*	50*	53	52*	60	54	57	56·5
58	61	61	60	60	61	62	61	62	59	60	63	59·2
58	58	60	60	57	58	59	58	58	60	59	62	58·8
64	66	65	64	61	61	62	62	63	64	64	64	62·1
64	66	66	66	65	62	62	62	63	64	64	64	62·2
66	66	65	63	59	64	64	63	64	62	59	68	63·5
54	53	55	57	54	58	57	57	57	56	56	58	58·3
55	54	57	58	58	48*	54	58	58	62	54	56	57·4
62	62	54	54	55	58	60	57	61	60	59	67	58·2
53	51*	55	57	59	60	58	59	57	63	56	61	58·8
58	55	54	54	57	58	59	58	59	58	58	60	57·8
57	58	58	59	59	59	60	59	58	57	56	56	58·4
60·7	61·0	60·3	59·8	59·0	59·6	60·4	60·7	60·9	61·1	60·8	62·5	60·82
60·3	61·8	61·1	61·3	60·9	61·5	61·0	61·1	61·7	61·1	60·4	62·5	

DIFFERENTIAL MEASURES—

Hourly readings from the photographic traces of the bifilar

[Local mean time. 200 divisions plus tabular quantity, one division = 0·000109 in parts of H. All

OCTOBER, 1888.

[For the explanation of these tables see pp. 53, 54.]

Day.	1^h	2^h	3^h	4^h	5^h	6^h	7^h	8^h	9^h	10^h	11^h	Noon.
1	56	58	59	61	61	61	60	58	57	58	61	58
2	61	61	62	62	61	59	58	54	53	56	58	60
3	62	63	62	63	64	63	65	56	55	58	61	63
4	66	65	65	66	64	64	60	60	58	60	63	64
5	60	62	60	69	64	63	61	56	52	50	50	54
6	59	60	58	61	62	62	57	56	51	52	57	56
7	63	62	63	61	62	60	58	53	53	54	57	58
8	61	61	60	60	60	60	59	56	54	55	58	61
9	60	61	61	63	62	61	61	59	55	54	58	58
10	66	63	63	63	64	62	61	59	57	58	54	54
11	59	60	62	64	63	64	64	61	58	56	54	50
12	57	58	64	60	60	61	60	58	56	53	53	52
13	57	55	57	59	61	59	61	58	56	60	60	60
14	57	65	60	59	60	59	58	57	58	62	63	60
15	59	59	60	60	60	60	61	61	62	62	63	62
16	59	60	62	63	62	62	59	58	57	55	56	54
17	64	63	64	63	62	61	60	59	59	61†	63†	62
18	61	61	61	60	63	63	62	62	62	62	63	62
19	64	69	68	66	67	60	63	62	61	58	52	50
20	61	55	59	60	60	61	62	59	58	54	44*	50
21	56	58	64	60	56	56	58	57	57	56	53	52
22	57	58	58	58	58	59	59	60	56	54	54	55
23	61	58	63	56	57	62	60	57	57	56	55	55
24	59	58	59	61	61	62	62	61	56	53	51	53
25	56	60	56	58	60	60	57	58	55	53	54	57
26	58	58	60	60	60	61	61	60	55	55	57	57
27	57	57	63	59	60	60	61	60	58	56	57	58
28	60	60	61	60	60	60	61	61	61	60	60	60
29	58	58	59	60	60	60	60	59	58	59	60	60
30	61	62	62	62	63	63	62	60	58	56	56	67*
31	57	56	59	60	61	59	60	57	57	56	57	58
Monthly mean	59·7	60·1	61·1	61·2	61·2	60·9	60·4	58·5	56·8	56·5	56·8	57·4
Normal	59·7	60·1	61·1	61·2	61·2	60·9	60·4	58·5	56·8	56·5	57·3	57·1

†Eye readings.

HORIZONTAL INTENSITY.

magnetometer of the Los Angeles Magnetic Observatory.

readings referred to standard temperature of magnet. Increasing numbers indicate increasing force.]

OCTOBER, 1888.

13^h	14^h	15^h	16^h	17^h	18^h	19^h	20^h	21^h	22^h	23^h	Mid-night.	Daily mean.
60	60	61	60	60	61	62	60	60	61	61	61	59·8[d]
60	61	61	60	61	62	61	61	61	61	61	60	59·8
64	63	63	63	63	63	63	64	65	66	66	66	62·7
66	68*	66	65	65	66	65	65	66	64	57	58	63·6
59	56	56	55	53	54	57	58	58	57	59	58	57·5
57	58	59	58	61	62	60	61	58	59	61	62	58·6
59	58	60	62	63	62	61	60	59	58	59	60	59·4
60	60	62	63	63	62	62	59	59	58	61	60	59·8
58	58	61	60	60	59	60	62	60	58	59	59	59·4
56	58	55	59	59	57	55	55	52	56	58	59	58·5
58	60	61	60	57	44*	55	58	45*	54	52	57	57·3
55	55	59	60	59	60	55	52	55	54	55	63	57·2
58	55	54	54	55	55	57	55	56	57	57	58	57·3
59	57	58	59	60	60	60	59	59	60	59	58	59·4
60	60	60	61	61	61	62	60	58	58	57	58	60·2
55	57	59	60	61	62	60	58	55	56	57	61	58·7
61	59	59	58	58	59	59	59	59	59	60	62	60·5
61	60	60	60	60	60	60	60	60	61	61	70*	61·4
44*	41*	38*	41*	45*	54	53	54	53	55	56	52	55·3
52	50	42*	50	49*	50	50	46*	52	47*	53	56	53·3
47*	53	54	52	52	52	52	54	55	57	63	57	55·5
57	58	60	60	60	59	58	59	58	58	59	58	57·9
51	53	51	56	58	57	56	53	56	55	56	58	56·5
53	52	53	55	56	53	56	58	54	53	60	56	56·5
57	58	57	55	56	51	56	54	57	57	58	58	56·6
58	56	55	57	58	58	57	56	59	56	56	55	57·6
58	58	58	58	58	58	58	57	58	60	58	59	58·5
59	60	61	61	61	60	59	59	58	58	57	57	59·8
60	59	58	59	60	61	61	60	60	59	59	60	59·5
70*	70*	66	64	66	66	62	36*	42*	53	49	54	59·6
39*	49	51	49*	54	43*	54	55	50	53	53	59	54·4
57·1	57·4	57·4	57·9	58·5	57·8	58·3	57·0	56·7	57·4	58·0	59·0	58·46
58·2	57·2	58·6	58·8	59·2	58·8	58·3	58·1	57·6	57·7	58·0	58·6	

DIFFERENTIAL MEASURES—

Hourly readings from the photographic traces of the bifilar

[Local mean time. 200 divisions plus tabular quantity, one division = 0·000109 in parts of H. All

NOVEMBER, 1888.

[For the explanation of these tables see pp. 53, 54.]

Day.	1^h	2^h	3^h	4^h	5^h	6^h	7^h	8^h	9^h	10^h	11^h	Noon.
1	55	57	57	58	56	59	61	62	59	56	54	53
2	59	59	58	58	59	60	59	63	60	59	59	58
3	61	58	59	60	60	59	60	60	61	60	60	60
4	60	58	59	60	60	61	56	60	63	56	59	56
5	60	58	58	57	61	59	57	54	55	57	56	56
6	56	56	56	56	56	58	54	54	54	55	56	56
7	56	58	58	61	61	62	59	58	60	55	54	57
8	54	55	56	57	58	59	59	62	61	65	54	59
9	54	59	58	57	57	57	58	59	58	58	54	53
10	56	57	57	58	58	58	57	57	56	54	51	50
11	54	54	56	55	54	56	55	55	57	56	53	53
12	56	56	58	56	56	57	57	55	54	52	52	52
13	59	60	60	61	61	60	60	59	56	54	55	58
14	59	59	59	60	58	57	57	58	57	54	53	54
15	60	60	60	61	61	61	60	60	60	62	63	63
16	50	52	52	57	57	58	61	61	63	60	55	46
17	41*	48*	61	48*	52	52	53	54	55	49	54	49
18	51	56	56	52	53	54	55	53	56	52	46*	50
19	54	55	57	52	57	56	54	56	54	53	49	47
20	56	56	57	57	57	57	58	58	62	53	51	47
21	54	55	58	57	56	57	57	57	57	56	53	55
22	56	59	57	56	57	59	59	59	60	58	54	53
23	58	57	58	58	59	59	60	59	58	56	54	54
24	59	60	60	60	60	61	61	62	60	59	58	59
25	60	61	62	62	62	64	65	67	67	64	63	58
26	55	58	60	60	62	62	64	67	67	67*	64	63
27	56	59	58	61	62	63	64	66	66	66*	60	57
28	57	59	59	59	59	59	61	61	60	57	56	58
29	57	59	58	59	59	59	60	60	62	60	58	57
30	59	59	58	58	59	59	59	62	61	57	51	53
Monthly mean	56·1	57·2	58·0	57·7	58·2	58·7	58·7	59·3	59·3	57·3	55·3	54·8
Normal	56·6	57·6	58·0	58·0	58·2	58·7	58·7	59·3	59·3	56·7	55·6	54·8

HORIZONTAL INTENSITY—Continued.

magnetometer of the Los Angeles Magnetic Observatory.

readings referred to standard temperature of magnet. Increasing numbers indicate increasing force.]

NOVEMBER, 1888.

13h	14h	15h	16h	17h	18h	19h	20h	21h	22h	23h	Mid-night.	Daily mean.
48	54	56	54	57	57	56	56	56	58	60	59	56·6d
59	58	57	56	57	60	59	59	59	59	59	58	58·8
60	60	60	60	60	60	59	59	58	57	57	57	59·4
59	56	54	48*	48	55	54	54	56	57	54	54	56·5
53	54	54	57	57	56	50	53	51	52	54	54	55·5
52	49	58	58	52	46*	50	51	50	54	52	55	53·9
54	51	52	54	56	57	55	55	55	55	54	53	56·3
52	48	50	52	54	52	52	53	55	54	55	54	55·4
54	55	55	57	56	55	57	54	55	55	56	55	56·1
50	52	57	60	61	62	59	62	58	59	47	63	56·6
53	55	58	58	57	54	55	56	55	55	54	56	55·2
52	54	56	59	60	61	60	60	59	58	60	59	56·6
58	59	59	60	60	60	60	60	60	60	59	59	59·0
55	56	58	60	61	60	61	60	62	59	58	60	58·1
62	63	65	61	51	54	51	49	47	46*	46*	47	57·2
52	53	55	53	50	49	49	44*	52	47*	50	46*	53·0
42*	45*	53	55	51	49	50	53	49	57	51	49	50·8
49	50	53	54	54	51	56	53	52	57	54	54	53·0
49	51	54	56	57	57	56	54	56	54	53	53	53·9
48	51	55	58	58	57	56	55	54	53	54	53	55·0
55	55	54	56	57	56	55	55	56	56	56	56	55·8
53	55	58	59	59	58	57	56	57	57	57	57	57·1
56	57	60	61	61	61	60	59	60	59	60	60	58·5
58	58	60	61	62	61	61	61	61	60	59	59	60·0
58	54	54	50	55	57	57	56	56	55	56	54	59·0
62	64*	64	60	58	62	61	61	59	58	56	52	61·1
53	55	56	60	60	52	61	60	53	56	56	53	58·9
55	50	58	59	59	59	58	55	54	59	62	59	58·0
55	56	57	59	58	58	58	57	59	58	59	60	58·4
53	55	57	59	60	59	60	60	60	58	60	58	58·1
53·8	54·4	56·6	57·1	56·9	56·5	56·4	56·0	55·8	56·1	55·6	55·5	56·72
54·2	54·4	56·6	57·4	56·9	56·9	56·4	56·4	55·8	56·8	55·9	55·9	

DIFFERENTIAL MEASURES—

Hourly readings from the photographic traces of the bifilar

[Local mean time. 200 divisions plus tabular quantity, one division = 0·000109 in parts of H. All

DECEMBER, 1888.

[For the explanation of these tables see pp. 53, 54.]

Day.	1^h	2^h	3^h	4^h	5^h	6^h	7^h	8^h	9^h	10^h	11^h	Noon.
1	58	59	60	60	60	60	61	61	63	62	61	60
2	58	65	60	58	58	58	60	61	64	64	62	61
3	60	61	62	62	62	61	63	64	61	63	60	58
4	59	60	59	58	60	59	61	62	61	61	60	59
5	58	60	61	60	60	60	57	60	60	62	60	58
6	55	56	58	58	62	61	60	60	59	60	56	53
7	57	58	58	59	60	60	62	63	64	62	58	55
8	52	56	55	65	63	67	64	64	57	52	54	51
9	54	56	56	56	56	58	57	60	60	57	54	53
10	56	57	58	58	59	59	60	62	61	59	56	52
11	58	58	59	59	60	60	60	61	62	60	56	52
12	58	58	59	59	60	61	62	62	62	61	62	59
13	60	62	61	60	62	63	63	63	63	60	56	55
14	57	60	65	64	62	64	63	63	56	60	58	57
15	60	56	53	55	55	58	54	57	56	50	53	53
16	55	54	57	57	57	57	59	56	53	54	53	51
17	56	56	57	58	57	57	58	59	59	57	54	54
18	57	58	58	58	59	59	59	60	61	59	58	57
19	57	57	58	58	58	59	60	61	60	58	56	56
20	56	56	58	58	58	60	60	60	61	61†	55†	53
21	58	59	58	59	59	58	58	61	60	59	57	56
22	55	56	57	59	60	61	62	64	64	62	58	56
23	53	59	61	60	59	61	61	63	63	59	54	51
24	47*	50	54	53	53	56	56	54	55	52	49	45*
25	54	52	58	57	53	53	52	53	53	52	51	50
26	55	55	56	57	59	63	60	58	54	50	47	46
27	54	55	55	56	56	56	56	56	54	50	47	46
28	56	56	57	57	58	59	59	59	59	59	56	56
29	49	60	59	60	60	62	63	64	63	60	55	56
30	61	58	58	59	60	61	62	63	61	58	55	54
31	62	62	63	64	66	62	63	63	62	61	60	58
Monthly mean	56·3	57·6	58·3	58·7	59·1	59·8	59·9	60·5	59·7	58·2	55·8	54·2
Normal	56·6	57·6	58·3	58·7	59·1	59·8	59·9	60·5	59·7	58·2	55·8	54·5

† Eye readings.

HORIZONTAL INTENSITY—Continued.

magnetometer of the Los Angeles Magnetic Observatory.

readings referred to standard temperature of magnet. Increasing numbers indicate increasing force.]

DECEMBER, 1888.

13^h	14^h	15^h	16^h	17^h	18^h	19^h	20^h	21^h	22^h	23^h	Mid-night.	Daily mean.
58	60	61	62	64	64	64	62	59	57	60	56	60·5^d
59	55	58	61	59	58	57	59	58	62	60	59	59·8
56	58	57	57	59	61	59	57	57	58	59	59	59·7
59	58	58	61	59	58	57	56	56	58	58	58	59·0
57	60	60	59	59	54	54	55	54	50	49	54	57·5
52	52	57	60	58	59	58	56	56	56	57	57	57·3
54	55	53	58	57	57	56	55	53	54	53	51	57·2
50	51	53	53	50	50	53	54	53	53	53	54	55·3
54	55	57	60	61	59	58	58	56	56	56	56	56·8
53	54	57	60	60	59	59	58	58	58	58	58	57·9
51	53	56	58	59	59	59	58	58	57	57	58	57·8
57	57	57	58	58	60	60	60	60	59	59	60	59·5
52	53	54	55	54	56	55	53	53	52	56	56	57·4
54	58	58	60	59	57	56	52	42*	48	48	53	57·3
55	51	51	55	55	55	56	54	55	53	55	56	54·6
48	54	57	58	56	57	57	58	57	55	61	57	55·8
53	52	55	59	60	58	54	56	56	56	58	57	56·5
56	58	60	61	59	59	56	57	56	55	56	57	58·0
56	58	59	59	57	58	56	55	54	54	54	55	57·2
55	57	60	60	60	59	58	58	57	57	57	58	58·0
54	54	54	54	55	55	54	53	52	52	53	58	56·3
57	58	59	60	59	59	58	57	57	57	59	60	58·9
53	57	60	60	60	69*	60	40*	37*	33*	43*	42*	54·9
49	54	60	56	56	55	55	50	49	52	48	56	52·7
52	54	57	56	57	55	57	55	57	53	54	56	54·2
50	54	58	58	58	57	57	55	54	54	54	54	55·1
52	57	58	59	58	59	58	57	57	56	56	56	55·2
56	60	60	60	61	60	60	61	60	60	59	59	58·6
57	60	59	59	61	61	61	62	62	60	58	58	59·5
59	61	63	61	61	60	60	60	59	59	59	58	59·6
58	57	57	55	55	56	56	56	56	56	57	57	59·3
54·4	56·0	57·5	58·4	58·2	58·2	57·4	56·0	55·1	54·8	55·6	56·2	57·34
54·4	56·0	57·5	58·4	58·2	57·8	57·4	56·6	56·2	55·6	56·0	56·7	

DIFFERENTIAL MEASURES—

Hourly readings from the photographic traces of the bifilar

[Local mean time. 200 divisions plus tabular quantity, one division = 0·000109 in parts of H. All

JANUARY, 1889.

[For the explanation of these tables see pp. 53, 54.]

Day.	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	Noon.
1	56	57	58	58	59	59	60	63	60	61	58	55
2	56	54	54	54	56	57	59	59	60	58	58	57
3	58	58	59	58	58	58	58	60	62	60	54	54
4	59	60	59	59	60	59	60	59	58	57	55	57
5	58	58	58	58	58	59	59	58	55	[53]	[50]	[50]
6	[55]	[56]	[56]	[56]	[57]	[58]	[60]	[60]	[59]	57	54	53
7	56	62	58	60	60	62	62	62	60	52	47	46
8	53	54	55	56	56	58	58	59	58	54	51	54
9	59	60	60	59	60	62	62	62	61	56	52	52
10	60	62	62	64	61	60	62	62	63	58	52	50
11	56	55	61	59	60	59	60	60	63	59	54	53
12	60	60	57	57	57	58	59	61	60	57	53	56
13	56	58	58	58	58	57	57	59	59	59	54	54
14	55	56	56	58	58	59	62	61	61	58	56	58
15	58	57	58	58	59	61	61	62	63	64	63*	61
16	58	58	59	59	60	60	61	60	58	54	53	56
17	58	58	58	60	61	62	62	61	60	57	56	56
18	58	58	59	59	60	60	62	63	63	60	61	59
19	57	57	58	58	59	60	60	60	58	52	51	54
20	54	57	59	60	60	66	63	63	54	52	53	47
21	51	50	51	51	54	54	53	55	53	56	55	52
22	51	52	51	53	54	54	54	52	51	49	48	49
23	52	53	53	53	53	52	55	56	52	48	42*	42*
24	52	52	54	54	54	55	54	54	55	54	52	51
25	55	54	55	55	55	55	55	57	56	52	48	47
26	54	55	56	55	57	57	57	59	59	56	52	52
27	56	56	56	56	57	58	59	61	64	62	58	55
28	55	53	54	55	56	60	60	60	61	57†	54	52
29	59	56	56	57	57	58	59	62	61	60	57	57
30	57	57	57	57	58	58	59	58	60	60	54	52
31	53	52	53	54	55	55	57	58	59	58	57	58
Monthly mean	56·0	56·3	56·7	57·0	57·6	58·4	59·0	59·5	58·9	56·5	53·6	53·2
Normal	56·0	56·3	56·7	57·0	57·6	58·4	59·0	59·5	58·9	56·5	53·7	53·6

† Eye readings.

HORIZONTAL INTENSITY—Continued.

magnetometer of the Los Angeles Magnetic Observatory.

readings referred to standard temperature of magnet. Increasing numbers indicate increasing force.]

JANUARY, 1889.

13^h	14^h	15^h	16^h	17^h	18^h	19^h	20^h	21^h	22^h	23^h	Mid-night.	Daily mean.
58	56	57	56	53	48	48	50	52	52	51	57	55·9[d]
58	60	58	57	56	56	56	56	57	56	57	57	56·9
56	58	58	59	58	59	58	58	57	58	58	58	58·0
58	60	61	61	58	58	57	56	57	57	57	57	58·3
[52]	[54]	[55]	[56]	[55]	[54]	[54]	[54]	[54]	[54]	[54]	[54]	[55·2]
58	61	63	65	62	60	60	60	59	58	58	58	[58·5]
55	60	61	57	58	53	53	51	50	48	55	53	55·9
58	63	63	61	62	61	59	61	61	60	59	59	58·0
56	58	57	58	59	58	57	59	60	59	60	60	58·6
56	59	57	57	56	60	58	59	58	58	57	56	58·6
56	58	59	59	57	55	56	54	57	57	57	56	57·5
55	56	59	56	56	57	57	58	59	55	57	57	57·4
56	58	58	57	57	56	57	56	56	57	56	56	57·0
58	58	58	57	57	57	57	57	57	58	58	58	57·8
60	61	60	60	59	58	59	58	58	58	58	58	59·7
59	61	62	62	60	60	59	59	60	60	59	59	59·0
58	59	61	62	61	59	60	59	59	59	58	57	59·2
61	63	63	60	59	59	58	57	58	57	57	57	59·6
60	63	54	65	62	60	59	58	58	51	48	49	57·1
47	46*	48*	49*	49	46*	49	45*	45*	47	45*	54	52·4
54	56	54	54	53	54	53	52	52	55	52	52	53·2
52	53	55	55	53	52	52	51	50	50	50	52	51·8
51	55	58	58	56	54	55	54	53	53	52	51	52·5
52	55	58	58	57	55	55	55	55	54	54	53	54·3
48	52	57	58	56	53	50	53	54	54	55	54	53·7
53	53	54	56	58	57	57	56	56	56	55	55	55·7
52	52	55	58	62	62	60	59	57	57	57	56	57·7
52	54	55	56	58	59	59	58	57	58	57	54	56·4
55	54	56	59	58	58	59	59	57	57	56	55	57·6
52	56	55	56	55	54	55	55	53	54	54	54	55·8
59	57	58	59	56	55	55	53	56	56	56	56	56·0
55·3	57·1	57·6	58·1	57·3	56·4	56·2	55·8	55·9	55·6	55·4	55·5	56·62
55·3	57·4	58·0	58·4	57·3	56·7	56·2	56·2	56·2	55·6	55·7	55·5	

DIFFERENTIAL MEASURES—

Hourly readings from the photographic traces of the bifilar

[Local mean time. 200 divisions plus tabular quantity, one division = 0·000109 in parts of H. All

FEBRUARY, 1889.

[For the explanation of these tables see pp. 53, 54.]

Day.	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	Noon.
1	56	56	57	58	58	58	58	58	58	57	54	53
2	55	55	55	56	56	57	57	56	55	52	51	51
3	58	58	58	59	59	60	60	60	61	56	48	50
4	53	54	54	54	55	55	54	54	54	52	49	48
5	55	57	57	58	58	58	58	58	58	57	54	54
6	56	56	57	59	59	59	58	59	60	60	56	54
7	54	55	56	57	59	60	58	67*	67*	64	62	59
8	52	58	56	55	54	57	56	54	52	48	49	52
9	55	56	56	57	58	58	59	58	58	56	53	50
10	57	57	57	57	57	58	58	59	59	58	56	55
11	57	57	58	58	58	58	57	56	57	56	53	50
12	56	57	57	57	57	57	58	56	57	53	49	50
13	56	57	58	58	60	60	59	59	56	[57]	58†	58
14	59	59	58	59	59	60	59	61	63	61	61	60
15	56	56	56	56	57	56	56	56	55	53	51	52
16	55	55	55	55	55	55	53	55	53	52	52	51
17	52	52	52	55	58	57	54	57	56	52	51	51
18	51	52	51	53	53	51	52	54	52	52	51	45
19	53	52	53	53	53	53	54	54	55	55	54	53
20	53	51	52	52	52	52	53	51	50	51	50	49
21	54	54	54	54	54	54	55	55	55	54	54	54
22	56	56	56	57	56	56	57	58	57	57	56	53
23	56	56	56	57	57	56	56	56	57	56	56	56
24	57	57	57	58	59	59	59	59	58	58	58	58
25	58	58	59	59	59	59	59	59	59	58	58	59
26	58	58	58	57	57	58	59	59	59	59	59	59
27	57	58	58	58	59	58	57	58	59	56	59	59
28	58	58	58	59	58	58	58	58	58	58	59	60
Monthly mean	55·5	55·9	56·0	56·6	56·9	57·0	56·8	57·3	57·1	55·6	54·3	53·7
Normal	55·5	55·9	56·0	56·6	56·9	57·0	56·8	56·9	56·7	55·6	54·3	53·7

†Mirror changed by observer between 9 and 11 a. m., requiring a correction of — 16·0 divisions to all subsequent readings for change of zero of scale; this has been applied.

HORIZONTAL INTENSITY—Continued.

magnetometer of the Los Angeles Magnetic Observatory.

readings referred to standard temperature of magnet. Increasing numbers indicate increasing force.]

FEBRUARY, 1889.

13^h	14^h	15^h	16^h	17^h	18^h	19^h	20^h	21^h	22^h	23^h	Mid-night.	Daily mean.
57	59	59	57	56	56	55	55	55	55	56	55	56.5d
54	54	55	56	55	55	55	54	57	56	56	56	55·0
50	54	55	56	55	55	55	54	54	54	53	53	55·6
49	50	54	56	59	58	58	57	56	56	55	55	54·1
54	56	58	59	59	59	57	55	53	54	55	55	56·5
57	58	57	53	53	52	52	51	53	56	54	53	55·9
56	56	52	56	54	55	56	55	50	52	53	52	56·9
49	52	54	57	57	57	57	55	55	55	55	55	54·2
51	54	57	57	57	56	55	55	55	55	55	56	55·7
54	56	57	58	59	58	58	57	57	56	57	57	57·2
51	53	55	56	56	56	56	55	56	56	56	56	55·7
53	56	58	59	60	59	59	58	58	57	57	56	56·4
60	60	61	61	61	61	61	61	61	61	60	60	[59·3]
60	57	57	56	57	58	59	58	58	58	57	57	58·8
53	54	55	55	54	52	54	53	52	51	53	54	54·2
50	51	52	55	54	55	54	54	53	53	52	52	53·4
51	52	50	48	51	52	50	51	51	47	50	50	52·1
43*	47	51	53	53	52	54	52	52	53	53	52	51·3
51	50	50	53	52	52	53	51	50	51	51	52	52·4
50	52	54	55	54	55	54	54	54	54	53	54	52·5
54	54	53	56	56	56	55	56	56	56	56	56	54·8
54	56	55	57	55	51	51	52	53	54	54	55	55·1
56	56	56	57	58	58	58	57	57	57	57	57	56·6
57	56	58	58	59	59	59	58	57	58	58	59	58·0
59	59	61	60	60	60	59	59	59	58	58	58	58·9
58	59	58	58	60	59	57	58	57	58	56	57	57·7
56	57	59	60	58	59	57	58	59	58	58	58	58·0
61	62	59	62	62	60	59	55	51	51	54	57	58·0
53·9	55·0	55·7	56·6	56·6	56·2	56·0	55·3	55·0	55·0	55·1	55·2	55·76
54·3	55·0	55·7	56·6	56·6	56·2	56·0	55·3	55·0	55·0	55·1	55·2	

APPENDIX No. 5.—1891.

ON THE MAGNETIC OBSERVATIONS MADE DURING BERING'S FIRST VOYAGE TO THE COASTS OF KAMCHATKA AND EASTERN ASIA IN THE YEARS 1725 TO 1730.

Submitted for publication as a Bulletin, December 12, 1890, and first published February 26, 1891.*

Discussion by C. A. SCHOTT, Assistant, and Chief of the Computing Division.

The observations for the "variation of the compass" made by Captain Bering along the coast of Kamchatka and northeasterly to the strait named after him derive their special value from the fact that they were made on a voyage of discovery, and are therefore the first ones in this region available for discussion of the secular variation of the declination. The observations are quite numerous; they extend over the western part of Bering Sea and from Cape Lopatka, Kamchatka, to East Cape, Siberia. Attention was first called to them by Dr. W. H. Dall, of the U. S. National Museum, in a letter addressed to the Superintendent of the U. S. Coast and Geodetic Survey and dated June 23, 1890.

The magnetic declinations given below I have extracted from Bering's log book of his first expedition from Okhotsk to East Cape, between the years 1725 and 1730. The record is from the version of Peter Chaplin (Tchaplin), printed in Russian by Vasili Bergh in 1823, and rendered into English by W. H. Dall, who presented his manuscript, together with two original charts, to the Superintendent of the Survey.

The names of the observers are not given, but the declinations are supposed to have been recorded by one or the other of the principal officers, viz, Vitus Ivanovich Bering, fleet captain; Martin Spanberg and Alexie Chirikoff, lieutenants; Peter Chaplin, midshipman, and Feodor Luzhin, surveyor.

With perhaps two exceptions, the observations were made on board ship, and by the method of the sun's amplitude when rising or setting. Dr. Dall's manuscript contains a table of the principal dates of the

* It has been deemed desirable to republish this paper in order to give it a permanent form as a contribution of value to our knowledge of the secular variation of the magnetic declination.

expedition in new style and civil count, yet the Gregorian dates assigned by me to the magnetic observations may be out one day (possibly two) for want of sufficient information as to the part of day intended (Bering counted from noon). Respecting the ship's position, the log or narrative is not sufficiently explicit to enable us to plot the courses sailed over. I have, therefore, retained the observed latitudes given in connection with the declinations and supplied the longitudes as well as I could from modern data. The geographical positions of the magnetic stations are, therefore, approximations; yet they are near enough for the purpose in hand. The longitudes are reckoned to 180° east and west from Greenwich, and the dates for those places whose longitude exceeded 180° east were diminished by one day in order to correspond to Western (American) reckoning.

Magnetic observations made by Bering in Kamchatka and along the Eastern Coast between the southern point of Kamchatka and Bering Strait, Eastern Siberia.

No.	Locality.	Latitude.	Longitude.	Year.	Date.	Declination east.
		° ′	° ′			° ′
1	Bolsheretsk, southwest'n Kamchatka.	52 45	156 45 E.	1727	Sept. 15	10 28
2	Upper Kamchatka, settlement.	54 28	159 00 E.	1728	Feb. 6	11 34
3	Off the Cape, near Lower Kamchatka, settlement.	56 03	162 40 E.	1728	July 24	13 10
4	Off Cape Kamchatka (near Cape Stolbovi).	56 30	163 40 E.	1728	July 25	14 45
5	Between Capes Kamchatka and Ozernoi.	57 00	163 30 E.	1728	July 26	16 59
6	Off Ukinskoi Point.	57 59	163 00 E.	1728	July 27	18 48
7	Off Cape Oliutorsk.	60 16	171 30 E.	1728	July 31	16 56
8	Southwest of Cape Omchinski.	61 03	174 00 E.	1728	Aug. 2	19 37 25 24*
9	West of Cape Omchinski.	61 32	176 00 E.	1728	Aug. 4	24 00 (?)
10	Off Bay of St. Gabriel (off Cape Navarin).	62 15	180 00	1728	Aug. 6	21 05 21 15
11	Off Cape Chukotski Nos.	64 10	173 00 W.	1728	Aug. 19	26 38 26 54
12	Off Cape Chaplin or Indian Point.	64 59	171 45 W.	1728	Aug. 22	25 31
13	Off St. Laurence Island.	64 10	172 00 W.	1728	Aug. 28	26 20 27 02
14	About 25 miles east of Cape Thaddeus.	62 20	179 50 W.	1728	Aug. 31	20 00
15	Off the Coast, between Capes Thaddeus and Kamchatka.	61 44	179 00 E.	1728	Sept. 2	18 40
16		61 30	178 00 E.	1728	Sept. 3	18 53 (?)
17		60 18	174 00 E.	1728	Sept. 5	18 32 18 15
18		57 35	165 00 E.	1728	Sept. 9	16 27
19	Off Cape Kronotzki.	54 07	163 00 E.	1729	June 19	11 50
20	Off Cape Tschipunski (Shipunski).	53 13	161 00 E.	1729	June 20	8 31 8 46
21	Kronotzki Bay.	54 12	162 00 E.	1729	July 3	11 50 10 47
22	Off Coast south of Petropavlovsk.	52 01	158 00 E.	1729	July 9	7 42
23	Off Cape Lopatka, east of it.	52 18	156 30 E.	1729	July 13	11 00

* Excluded.

For the purpose of utilizing these observations for the investigation of the secular variation of the declination and for forming an estimate of their intrinsic value, it will be necessary to express them by an interpolation formula depending on the latitude and longitude of the magnetic stations.

It suffices to take four terms of the general formula usually applied in such cases, viz:

$$D = D_1 + u + \varDelta\varphi . v + \varDelta\lambda \cos\varphi . w + \varDelta\varphi^2 . x + \varDelta\lambda^2 \cos^2\varphi . y$$

where D = resulting declination, D_1 an approximate value for the normal position, φ_0 and λ_0, and u a correction to it.

φ = latitude of any station.

$\varDelta\varphi = \varphi - \varphi_0$ = difference in latitude, φ_0 being the adopted normal latitude.

$\varDelta\lambda = \lambda - \lambda_0$ = difference in longitude, λ_0 being the adopted normal longitude.

u = a constant and v, w, x, and y coefficients to be determined by the method of least squares from the observations themselves.

In order to shorten the labor in the application of this formula, the observations, after having been plotted on illustration No. 26, Coast and Geodetic Survey Report for 1888–'89 (Isogonic chart of Alaska and adjacent regions), were found readily to group themselves for average values, as follows:

Numbers.	φ	λ (east).	D (east).
	°	°	°
23, 1, 22	52·36	157·08	9·72
2, 20, 21, 19	54·00	161·25	10·84
3, 4, 5, 6, 18	57·02	163·56	16·03
7, 17, 8	60·54	173·17	18·31
15, 10, 14	62·10	179·72	19·95
11, 13, 12	64·44	187·75	26·32
Mean.	$\varphi_0 = 58{\cdot}41$	$\lambda_0 = 170{\cdot}42$	$D_1 = 16{\cdot}86$

Observations Nos. 9 and 16 of the general table were omitted as defective or locally affected.

The observation equations and the five normal equations were formed and solved, whence the east declination for the epoch 1728·5.

$$D = 15^\circ{\cdot}25 + 1{\cdot}929\,\varDelta\varphi - 0{\cdot}436\,\varDelta\lambda\cos\varphi - 0{\cdot}1242\,\varDelta\varphi^2 + 0{\cdot}1172\,\varDelta\lambda^2\cos^2\varphi$$

where $\varDelta\varphi = \varphi - 58^\circ{\cdot}41$

$\varDelta\lambda = \lambda - 170^\circ{\cdot}42$ (east).

This equation* satisfies the observations, as follows:

No.	Observed D (east).	Computed D (east).	Diff. O—C.	No.	Observed D (east).	Computed D (east).	Diff. O—C.
	°	°	°		°	°	°
1	10·47	11·98	— 1·51	13	26·68	25·78	+ 0·90
2	11·57	13·79	— 2·22	14	20·00	21·34	— 1·34
3	13·17	14·07	— 0·90	15	18·67	20·46	— 1·79
4	14·75	14·37	+ 0·38	16	13·88 (?)	19·98	(— 6·10)?
5	16·98	15·58	+ 1·40	17	18·40	18·06	+ 0·34
6	18·80	17·91	+ 0·89	18	16·45	15·83	+ 0·62
7	16·93	18·21	— 1·28	19	11·83	8·78	+ 3·05
8	19·62	19·09	+ 0·53	20	8·64	8·09	+ 0·55
9	24·00 (?)	19·73	(+ 4·27)?	21	11·30	9·92	+ 1·38
10	21·17	21·21	— 0·04	22	7·70	8·04	— 0·34
11	26·77	25·22	+ 1·55	23	11·00	11·00	0·00
12	25·52	25·95	— 0·43				

The probable error of a single observation is given by the expression

$$0{\cdot}674\sqrt{\frac{(vv)}{n-\nu}} = 0{\cdot}674\sqrt{\frac{33{\cdot}34}{21-5}} = \pm\, 0^\circ{\cdot}97$$

but if we admit the differences of Nos. 9 and 16 this value changes to $\pm$ 1°·50. We may fairly ascribe a probable uncertainty of $\pm$ 1¼° to Bering's records, which, considering the times, must be taken as evidence of carefully made observations.

The expression for the distribution of the declination, as resulting from Bering's records, can be brought to bear with good effect on the formulæ deduced for the secular variation at three stations. They are Petropavlovsk, Kamchatka, Port Clarence, and Chamisso Island, Alaska. Referring for further information to Appendix No. 7, Coast and Geodetic Survey Report for 1888, the formulæ there given should be changed to the following:

For Petropavlovsk $\varphi = 53^\circ\ 01'$ $\lambda = 158^\circ\ 43'$ E.
For Port Clarence $\varphi = 65^\circ\ 16'$ $\lambda = 166^\circ\ 50'$ W.
For Chamisso Is'd $\varphi = 66^\circ\ 13'$ $\lambda = 161^\circ\ 49'$ W.

$$D = -\ 5^\circ{\cdot}53 + 3^\circ{\cdot}62 \sin (1{\cdot}15m + 54^\circ{\cdot}6)$$
$$D = -26^\circ{\cdot}09 + 4^\circ{\cdot}41 \sin (1{\cdot}2\ m + \ 4^\circ{\cdot}6)$$
$$D = -29^\circ{\cdot}88 + 4^\circ{\cdot}35 \sin (1{\cdot}2\ m + \ 2^\circ{\cdot}6)$$

where m = year — 1850 and D = resulting declination for that year, the negative sign indicating *east* declination.

For these places we have from Bering's observations, as discussed above, the declinations — 10°·1, — 29°·1, and — 32°·6, respectively, for 1728, results which are fairly represented by the above local formulæ.

* A trial was made to introduce an additional term (depending on $\Delta\varphi\ \Delta\lambda \cos\varphi$), but it was found that the observations were not accurate enough to bear such a term, the effect of it producing an accord entirely artificial.

While the secular change expression for Petropavlovsk is greatly improved, that for Port Clarence, and consequently also the expression for Chamisso Island, in its vicinity, is totally changed. This is due to the extension of the latter formulæ over an additional century; yet modern observations are greatly needed before we can have some assurance that we are making substantial improvements. It is only by taking advantage of all information we can get that our knowledge of the laws of the secular variation gradually attains accuracy.

APPENDIX NO. 6—1891.

ON THE REDUCTION OF HYDROMETER OBSERVATIONS OF SALT-WATER DENSITIES.

Submitted for publication, February 18, 1890, by O. H. TITTMANN, Assistant, in charge of the Office of Standard Weights and Measures.

Revised for republication, February 1, 1892.

The hydrometers heretofore in use in the Coast and Geodetic Survey for determining the density of ocean water are described in Appendix 16, Coast Survey Report for 1874. They are of glass, of the usual form, and are decimally divided on the stem. Each hydrometer is accompanied by a copper vessel for holding the water, to which a thermometer is attached with the apparatus described in that appendix. Fahrenheit thermometers were used, and the densities given by the graduation of the hydrometer were referred to pure water at 60° F.

The introduction of the centigrade scale and of a graduation to give densities referred to pure water at 4° C. necessitates the publication of a convenient table for reducing the observations to the temperature of 15° C., recently adopted by this Survey and by the U. S. Fish Commission. The hydrometers hereafter issued will be standardized at this temperature.

The following table for the reduction of observed densities to 15° C. is taken from Dittmar, Physics and Chemistry, Challenger Expedition, Vol. 1, after applying to his densities one-half of the correction given by him for reducing them to Thorpe and Rucker's results. The temperature at which the density of the standard water is 1·02600 has been shifted from 15°·56 to 15° C. for the sake of getting an integer number. The table has been rearranged so as to give the densities of the standard water multiplied by 1000 for whole degrees and tenths from 0° to 30°·9 C. on one page.

The ratio designated $\varphi(t)$ by Dittmar is omitted, and only its reciprocal is given in the column headed m. The values there given appertain to the temperatures on the same horizontal lines given in the first

column. The use of this function is illustrated in the examples in which it appears as a multiplier for the purpose of allowing for the different rates of expansion between standard water and the water the density of which is being determined.

The last column has been added to this table for convenience, and gives the correction for change in the volume of the hydrometer itself. The values given have been computed for the mean reading 1026, and with the assumed coefficient of cubical expansion for glass $\alpha = \cdot 000025$.

The use of the table will appear from the following examples:

Example. I.	Example. II.	
° 23·0	° 10·5	Obs. temp.
— 0·1	— ·2	Corr. to thermometer.
22·9	10·3	Corrected temp. $= t$.
1021·00	1029·29	Observed hydr. reading.
— 0·20	+ ·12	Corr. for expansion of hydr. = a.
. .	. .	Corr. for hydrometer constant.
1020·80	1029·41	Observed density at t = OD.
1023·99	1026·92	Density of standard water at t = SD.
— 3·19	+ 2·49	OD — SD.
1·018	·987	m, tabular multiplier.
— 3·25	+ 2·46	m (OD — SD.)
1026·00	1026·00	Standard water at 15° C.
1022·75	1028·46	Corrected density at 15°.

For observations which have been reduced to 60° F., made with the old hydrometers indicating densities referred to pure water at 60° F., it will suffice to subtract the constant 0·82 from the result in order to convert the latter into absolute densities at 15° C.

Example: Given 1024·00 the density of salt water at 60° F. referred to pure water at 60° F., 1024·00 — 0·82 = 1023·18 its density at 15° C.

Table for Reducing Densities of Sea Water to 15° C.

Temp.	·0	·1	·2	·3	·4	·5	·6	·7	·8	·9	m	a
0°	1028·08	1028·07	1028·07	1028·06	1028·06	1028·05	1028·04	1028·04	1028·03	1028·03	·951	+ 0·38
1	·02	·01	·01	·00	·00	27·99	27·99	27·98	27·97	27·97	·955	·35
2	27·96	27·96	27·95	27·94	27·92	·92	·91	·90	·89	·88	·960	·33
3	·87	·87	·86	·85	·84	·83	·82	·81	·80	·79	·963	·30
4	·78	·77	·76	·75	·74	·72	·71	·70	·69	·68	·967	·27
5	·67	·66	·65	·64	·63	·61	·60	·59	·58	57	·970	·25
6	·56	·55	·53	·52	·51	·50	·48	·47	·46	·44	·973	.23
7	·43	·41	·40	·38	·37	·35	·34	·32	·31	·30	·976	·20
8	·28	·26	·25	·23	·22	·20	·19	·17	·16	·15	·980	·17
9	·13	·11	·10	·08	·07	·05	·03	·02	·00	26·98	·983	·15
10	26·97	26·95	26·93	26·92	26·90	26·88	26·86	26.84	26·83	·81	·986	·13
11	·79	·77	·75	·74	·72	·70	·68	·66	·65	·62	·989	·10
12	·61	·59	·57	·55	·53	·51	·49	·47	·45	·43	·992	·08
13	·41	·39	·37	·35	·33	·31	·29	·27	·25	·23	·995	·05
14	·21	·19	·17	·15	·13	·10	·08	·06	·04	·02	·997	·02
15	.00	25·98	25·95	25·93	25·91	25·88	25·86	25·84	25·82	25·79	1·000	·00
16	25·77	·75	·72	·70	·68	·65	·63	·61	·59	·56	1·003	— 0·02
17	·54	·52	·49	·47	·45	·42	·40	·38	·35	·33	1·005	·05
18	·30	·27	·25	·22	·20	·17	·14	·12	·09	·07	1·007	·08
19	·04	·01	24·99	24·96	24·94	24·91	24·88	24·86	24·83	24·80	1·009	·10
20	24·78	24·75	·73	·70	·68	·65	·62	·60	·57	·54	1·011	·13
21	·52	·49	·47	·44	·41	·39	·36	·33	·30	·28	1·012	·15
22	·25	·22	·19	·16	·13	·10	·08	·05	·02	23·99	1·015	·17
23	23·96	23·93	23·90	23·87	23·84	23·82	23·79	23·76	23·73	·70	1·018	·20
24	·67	·64	·61	·58	·55	·53	·50	·47	·43	·40	1·020	·23
25	·38	·35	·32	·29	·26	·23	·20	·17	·14	·11	1·022	·25
26	·09	·06	·03	23·00	22·97	22·93	22·90	22·87	22·84	22·81	1·024	·27
27	22·78	22·75	22·72	22·68	·65	·62	·59	·56	·53	·50	1·026	·30
28	·46	·43	·39	·36	·33	·29	·26	·23	·20	·16	1.027	·33
29	·13	·10	·06	·03	·00	21·96	21·93	21·90	21·87	21·84	1·029	·35
30	21·80	21·77	21·73	21·70	21·67	·63	·60	·57	·54	·50	1·031	·38

APPENDIX NO. 7—1891.

ON AN INVESTIGATION OF THE RELATIONS OF COLD AND WARM OCEAN CURRENTS OFF THE NEW ENGLAND COAST, BY THE U. S. FISH COMMISSION, WITH THE COÖPERATION OF THE U. S. COAST AND GEODETIC SURVEY.

By WILLIAM LIBBEY, jr., U. S. Fish Commission.

Submitted for publication December 21, 1891.

Through the courtesy of the U. S. Coast Survey, the steamer *Blake*, Lieut. C. E. Vreeland, U. S. N., assistant, Coast and Geodetic Survey, commanding, was detailed to investigate the relations of the cold and warm currents off the New England coast, under the direction of the writer, in connection with the work of the U. S. Fish Commission during the summer of 1890.

The region chosen for study was that lying between Block Island, on the west, and the eastern border of Nantucket Island, on the east, and extended 150 miles to the southward from these two islands. Between the eastern and western limits given above ten lines were laid out nearly at right angles to the coast and 150 miles long. These lines were thus located at intervals of ten minutes (of longitude) as nearly as possible, and upon each of them fifteen stations, also at intervals of ten minutes (of latitude), were placed, where observations were made upon the temperature and density of the water.

At each station observations were made upon the temperature of the water at the surface and at the following intervals in depth: 5, 10, 15, 20, 25, 30, 40, 50, 75, 100, and 200 fathoms in deep water, and the same intervals were used in shoal water as far as possible. The specific gravity of the water was observed at the surface and bottom of the water in every instance, and at intermediate depths where it was deemed advisable.

Work was begun upon July 9 and ended upon August 4; of this time, however, there were only nineteen actual working days. Between July 9 and July 16 six complete lines were run; between July 20 and July 24 four more were made, and between July 30 and August 4 the remaining five were made. This latter set of five covered the

same ground as the previous ten, using a 20-mile interval between the lines instead of one of 10 miles.

Accompanying these observations a complete set of meteorological records was made each hour while we were upon the ocean. Upon the first two trips of the *Blake* I was assisted by Mr. L. W. Mudge, and on the last trip Prof. C. G. Rockwood, jr., took my place, and he and Mr. Mudge made the remaining observations.

The astronomical work of navigation, the location of stations, etc., was done by the officers of the *Blake*, and we are indebted to Capt. Vreeland and his associates for much valuable aid throughout the whole time we were upon the vessel. Every facility was rendered us, and the resulting temperature profiles show the great advantages to be derived from such complete appliances and such able and willing coöperation.

In all about 2 500 observations were made upon the temperature of the water and 500 observations upon its specific gravity. In addition there were over 6 500 meteorological observations recorded. We occupied 225 stations upon the area where we had planned to work, and these stations are shown upon the map which will accompany the full report of our work. The observations have all been reduced and tabulated for publication, and 15 temperature profiles, giving the temperature curves of 50°, 55°, 60°, and 70°, have been prepared, which show the relations of the cold and warm bodies of water to one another very clearly, and give much more distinct ideas of their relative positions at the edge of the continental plateau.

The full report, which is rapidly nearing completion, involves the consideration of the other observations made by my parties in the service of the U. S. Fish Commission, viz, the schooner *Grampus*, which was at work upon the same area at the same time, and also a series made upon the Nantucket New South Shoal light-ship.

The report shows in brief that we have to deal with two different sets of currents.

1. Deep currents, flowing in two (generally opposite) directions, alongside of one another, whose courses are controlled more by the mechanical influence of the impact of one current upon the other, their relative velocities, etc., than by changes in temperature and density.

2. Surface currents, flowing in the same general directions as the deep currents and subject to the same mechanical laws, but whose courses are in addition affected to a very considerable degree by the frictional influence of the winds, and a peculiar condition which has not been found to hold for the deep currents, viz, an apparent reversal of portions of the warm current. The outlying bands of warmer and denser water, which pass off from the shore side of the Gulf Stream, are apparently drifted toward the shore or away from it to an amount dependent upon the direction, velocity, and duration of the winds, and when they are forced toward the shore, thus bridging over the colder

current, as they pass farther from the source of their original velocity they are overpowered and reversed. They retain much of their temperature and density, and this to a considerable depth, but their direction is sometimes at right angles and then opposite to that of their original course.

A more extended report upon the subject can not be presented at this time without involving a discussion which would need the help of the records, with the plates and maps accompanying them, to supplement the statements made. Enough has been said to indicate the nature of the investigation and the important addition made towards its solution by the help of the steamer *Blake.*

The practical object sought by the Fish Commission is to determine, if possible, the physical conditions which control the movements of the schools of fish.

As the temperature of the water controls the growth and distribution of the food of the fish, the study of the changes which take place in it and of their causes becomes a matter of considerable importance.

APPENDIX No. 8—1891.

ON THE CHANGES IN THE SHORE LINES AND ANCHORAGE AREAS OF CAPE COD (OR PROVINCETOWN) HARBOR AS SHOWN BY A COMPARISON OF SURVEYS MADE BETWEEN 1835, 1867, AND 1890.

A report by HENRY L. MARINDIN, Assistant.
Submitted for publication March 28, 1891.

The completion of the resurvey of Cape Cod Harbor* in 1890 has enabled us to make a comparison with its condition in 1867, and for parts of it with the earlier survey of 1835, and to ascertain what changes have obtained in the shores and depths of this most important harbor of refuge.

In order to realize the intrinsic value of this harbor as a port of refuge we may note the following statistics for the fiscal year ending July 1, 1890, kindly furnished by Mr. Myrick E. Atwood, deputy collector:

Number of vessels visiting this port for shelter,	4 000
Estimated value of commerce and navigation seeking shelter during the year,	$40 000 000
Number of entries from foreign ports,	27
Tonnage of vessels entered from foreign ports,	4 462
Number of clearances for foreign ports,	20
Tonnage of vessels cleared for foreign ports,	1 924
Number of vessels hailing from the port,	122

For some years prior to 1867 the citizens of Provincetown had entertained grave fears that the harbor was being silted up by the movement of sands from Laneys Harbor and House Point Island flats on one side, and from East Harbor on the other side, re-enforced by such material as might find its way into the harbor from the south side of Long Point.

In 1867 a call was made on the U. S. Coast Survey by the Harbor Commissioners of Massachusetts for a resurvey of the harbor of Provincetown; this resulted in a survey during that year by the party of

* The name first given to what is now generally known as Provincetown Harbor.

Assistant Henry L. Whiting, followed by a report published in Appendix No. 12, Coast Survey Report for 1867.

In this report Mr. Whiting discusses the results of a comparison made with the survey of Major Graham in 1835. The subjects were discussed under three heads: First, with reference to changes at Long Point and on House Point Island flats; second, East Harbor Inlet and Beach Point; and third, the Beaches at the head of East Harbor.

Some of the recommendations for improvement suggested by Mr. Whiting have been carried out. A dike was built by the United States at the "wading place" at High Head in 1868–'69; another dike was built across the outlet of East Harbor Creek, by the State of Massachusetts, effectually cutting off the water communication between East Harbor and the bay; and in 1870 still another dike was thrown across the head of Lancys* Harbor at Abel Hill to prevent the flow of the tide from Lancys Harbor into the main harbor. This dike was rebuilt in 1871.

A study of the results of the present comparison points decidedly to the conclusion that these improvements have in great measure arrested the forces which were working towards the injury of the harbor. The success of the dike at Abel Hill in arresting the wash of the sands from Lancys Harbor, only points with stronger emphasis to what should be done to arrest the wash of material from House Point Island flats.

So long as the low and narrow sandy barrier,† to the northward of Wood End Light-house, remains intact, the wash off the flats will remain at a minimum; but should the seas make a breach through the beach during a gale, there is no telling what damage might follow, and it would seem the part of prudence for the Government to heed the recommendation made by Mr. Whiting in 1867, and urged again in 1886 by Major Gillespie, U. S. Engineers, that a dike be built from Stevens Point, in Provincetown, to Long Point, thus effectually inclosing the whole of House Point Island flats.

The preservation of Long Point (a natural mole guarding the deep-water basin of the harbor), which has been in charge of the U. S. Engineers, should be advanced by ample appropriations from the General Government.

In preparing this report it was not our intention to go back to the survey of 1835, but the manner of comparison by areas was not pursued in the report of 1867, and furthermore the survey of 1867 did not determine the depth beyond the 18-foot curve; this left out of the comparison all the area of deeper water, and it was deemed instructive if not

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*Lancys Harbor is now a dry sand and gravel slough, the outlet into Herring Cove having been closed by the action of the sea.

†In 1889 the width of this beach from the high-water line outside to the high-water line inside of the harbor was only 50 feet. This width would be reduced one-half during a severe gale from the westward at the time of high water.

On the changes in the shore lines and anchorage areas of Cape Cod (or Provincetown) Harbor, etc.—Continued.

important to know the condition of this part of the harbor in 1835 and what changes had taken place up to 1890.

It was necessary, for our purpose, to set off a part of the bay as the harbor proper, and to identify the limits on all the surveys to be compared; this was done by drawing a line from Long Point light-house to the summit of Mount Gilboa as the eastern limit, and by calling all to the westward of this line the anchorage ground to be compared. This line is indicated on the accompanying comparative map (illustration No. 11).

By referring to this map, on which the position of the fathom curves is given as they existed in 1867 and 1889–'90, the following detailed statement of the changes in the area of anchorage ground will more readily be understood. We have also indicated on the map, by sharp contrast in shading, the places and extent of shift of contour under water and also (as in East Harbor) the areas covered by sands shifted by the winds (traveling dunes).

In 1835 that portion of the harbor with greater depth than 30 feet contained 487 acres; this was reduced to 474 acres in 1889, a loss of 13 acres in 54 years, or at the rate of five-hundredths of 1 per cent per year. There is reason to believe that the greater share of this reduction obtained before 1867, at which date the closure of East Harbor and Lancys Harbor had not been effected.

Between the 30-foot curve and the 24-foot curve the area in 1835 was 51 acres; in 1889 it was 58 acres, an increase of 7 acres, or at the rate of one-tenth of 1 per cent per year.

Between the 24-foot curve and the 18-foot curve the area was 137 acres in 1835 and 147 acres in 1889, showing again an increase of area, and at the rate of thirteen-thousandths of 1 per cent per year.

No comparison of the preceding areas could be made with the survey of 1867, as the soundings taken at that date were limited to 18 feet of depth.

Between the 18 and 12 foot contours, the area was found to have been 178 acres in 1835 and 175 acres in 1867, indicating a loss of area at the rate of five-hundredths of 1 per cent per year. In 1889 the area was again 178 acres, the same as 54 years before, and showing an increase of 3 acres since 1867, or at the rate of eight-hundredths of 1 per cent per year.

Between the 12 and 6 foot contours the area was 160 acres in 1835 and 163 acres in 1867, an increase at the rate of six-hundredths of 1 per cent per year. In 1889 the area was 159 acres, a loss of 4 acres since 1867, or at the rate of one-tenth of 1 per cent per year.

Between the 6-foot curve and the line of mean low water the area was 289 acres in 1835 and 238 acres in 1867, a loss of 51 acres, or at the rate of one-fifth of 1 per cent per year. In 1889, within the same limits,

the area was 258 acres, indicating an increase of area of 20 acres in 22 years, or four-tenths of 1 per cent per year.

If we compare the entire harbor area outside of the mean low-water line, we find that in 1835 this area was 1,302 acres, and that in 1867 it had been reduced to 1,247 acres, a loss of 55 acres in 32 years, or one-tenth of 1 per cent per year. Between 1867 and 1889 the area increased to 1,274 acres, or 27 acres in 22 years, which is at the rate of nine-thousandths of 1 per cent per year. These results are confirmed by an inspection of the comparative maps, which shows a resultant shoreward movement of the submerged contours and thus points to the conclusion that the conditions since 1867 are most favorable to the maintenance of the present depths.

In table No. 1 will be found tabulated the areas of anchorage ground for the years 1835, 1867, and 1889.

The data exhibited on illustration No. 11 extend beyond the limits reserved for this report; there is one feature, however, to which we would call special attention, and that is the large belt eroded from the outer shore of the cape in the vicinity of what was once East Harbor.

TABLE No. 1.—*Water areas in Cape Cod Harbor, west of a line drawn from Long Point to Mount Gilboa, 1835, 1867, 1889–'90.*

[Area in acres. The + sign denotes increasing area. The – sign denotes decreasing area.]

Limits embraced.	1835.	1867.	Per cent of yearly change 1835–1867.	1889–90.	Per cent of yearly change 1867–1889.
Outside of mean low-water line.	1 302	1 247	— 0·0013	1 274	+ 0·0009
Outside of 6 feet of depth.	1 013	1 009	— 0·0002	1 016	+ 0·0003
Outside of 12 feet of depth.	853	846	— 0·0003	857	+ 0·0006
Outside of 18 feet of depth.	675	671	— 0·0002	679	+ 0·0005
Outside of 24 feet of depth.	538	not given		532	
Outside of 30 feet of depth.	487	not given		474	

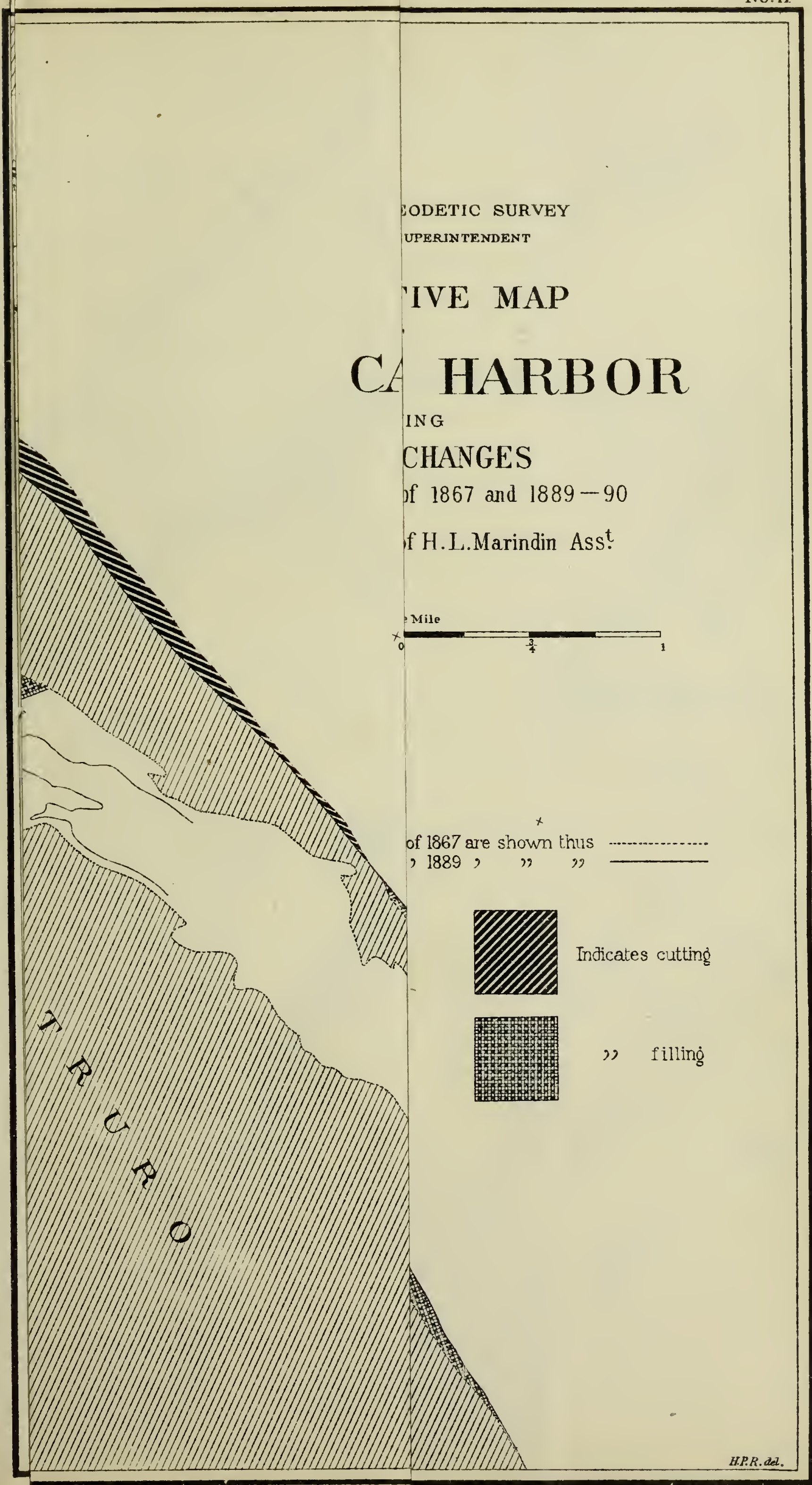
MOVEMENT OF THE BORDER OF HOUSE POINT ISLAND FLATS.

The encroachment of these flats on the harbor was noticed in 1867, and formed part of the discussion in Mr. Whiting's report of that date.

A comparison of the conditions in 1889 with those which prevailed in 1867 has been found interesting, and the results have been grouped on the accompanying sketch (illustration No. 12). We have illustrated the changes in the depth by shading lines, which indicate shoaling or deepening, the lightest shading representing 0 to 3 feet, the next heavier shading 3 to 6 feet, and so on. Where no change has been detected it is indicated by cross shading.

The area examined (which comprises the area covered by the soundings taken in 1867 on the slope between the line of mean low water and the contour at 30 feet of depth) covers 168 acres; of these 81 acres show shoaling, 67 acres show deepening, and 20 acres no change in depth.

The material brought to this slope since 1867 by the wash off the



No. 11
ODETIC SURVEY
UPERINTENDENT
IVE MAP
CA HARBOR
ING
CHANGES
of 1867 and 1889—90
f H.L.Marindin Ass^{t}
Mile
0
$\frac{3}{4}$
1
of 1867 are shown thus
" 1889 " " "
Indicates cutting
" filling
TRURO
H.P.R. del.


U.S. COAST AND GEODETIC SURVEY
T. C. MENDENHALL SUPERINTENDENT
COMPARATIVE MAP
OF
CAPE COD HARBOR
SHOWING
PHYSICAL CHANGES
Between the Coast Surveys of 1867 and 1889 – 90
To accompany Report of H. L. Marindin Ass!
Statute Mile
The fathom curves of 1867 are shown thus
" " " " 1889 " " "
Indicates cutting
" filling
PROVINCETOWN
EAST HARBOR
PART OF TRURO
Flats bare at Low Water
House Point Island
Long Pt. Lt.
Wood End Lt.
N

On the changes in the shore lines and anchorage areas of Cape Cod (or Provincetown) Harbor, etc.—Continued.

flats and from other sources amounts to 196,339 cubic yards, and the volume removed amounts to 162,019 cubic yards. which leaves an excess of shoaling of 34,320 cubic yards. Should this volume be spread evenly over the area of the slope the reduction in depth would amount to 1½ inch only; but the accumulation has taken place in spots, notably on the north side and near the end of Long Point, on a sharp slope of 1:4, as measured between the 6-foot and the 30-foot curves. The shoaling in this case is, however, in the direction of an improvement, in that it strengthens the end of the point, which has shown a tendency to erosion on the seaward side.

In the bottom of the bight, about halfway between Long Point and Union Wharf (see illustration No. 12), the comparison reveals in one place (section on A B) a retreat of the contours between 6 and 30 feet of depth, and in another place (section C D) a sharp advance of the edge of the flats. Where shoaling prevailed, the slope between the 6 and 30 foot contours has become steeper, from 1:8 in 1867 to 1:5 in 1889. Where deepening has obtained the reverse has taken place; the slope which in 1867 was 1:6 had become 1:9 in 1889, *i. e.*, both the deepening and the shoaling processes have gone on in the shallower depths of the slope.

The tabulation of the depths on cross sections, shown on illustration No. 12, will be found in the annexed tables Nos. 2 to 4.

The illustrations were drawn by Mr. Homer P. Ritter and the compilation of the data is the joint work of Mr. Ritter and myself.

TABLE NO. 2.*—*Sections on AB.*

1835.			1867.			1889.		
Distance from origin.	Depth at M. L. W.	Remarks.	Distance from origin.	Depth at M. L. W.	Remarks.	Distance from origin.	Depth at M. L. W.	Remarks.
Metres.	*Feet.*		*Metres.*	*Feet.*		*Metres.*	*Feet.*	
0	0	Origin at mean low water of 1835.	0			0		
			146	0	Mean low water, 1867.	123	0	Mean low water, 1889.
224	2	Low water (springs).	208	4		180	3	
			230	5½		214	6	
233	6		244	6		253	12	
248	12		273	12		263	18	
264	18		279	18		273	24	
274	24		285	24		281	30	
288	30		293	30		338	52	
309	39		298	32		423	59	
334	55		325	45		498	57	
392	53		363	55				
443	58							

* See illustration No. 12.

TABLE NO. 3.*—*Sections on CD.*

1835.			1867.			1889.		
Distance from origin.	Depth at M. L. W.	Remarks.	Distance from origin.	Depth at M. L. W.	Remarks.	Distance from origin.	Depth at M. L. W.	Remarks.
Metres.	*Feet.*		*Metres.*	*Feet.*		*Metres.*	*Feet.*	
0	0	Origin at mean low water, 1835.	0			0		
			150	0	Mean low water, 1867.	135	0	Mean low water, 1889.
161	2	Low water (springs).	192	1¾		170	¾	
			211	6		225	2¾	
210	6		245	12		245	6	
225	12		257	18		252	12	
234	18		264	24		260	18	
246	24		272	30		270	24	
257	30		290	37		280	30	
260	34		316	56		290	36	
307	58					470	54½	
391	57					670	52½	

* See illustration No. 12.

TABLE NO. 4.*—*Sections on EF.*

1835.			1867.			1889–'90.		
Distance from origin.	Depth at M. L. W.	Remarks.	Distance from origin.	Depth at M. L. W.	Remarks.	Distance from origin.	Depth at M. L. W.	Remarks.
Metres.	*Feet.*		*Metres.*	*Feet.*		*Metres.*	*Feet.*	
0	65	Origin at E.	0		Origin at E.	0		Origin at E.
47	68		167	74		12	62	
99	70		185	69		52	65	
189	73		206	56		85	66	
214	30		224	30		122	69	
261	6		241	6		152	71	
273	0	Mean low water, 1835.	252	0	Mean low water, 1867.	179	65	
						207	31	
334		High water, 1835.	297		High water, 1867.	226	6	
						243	1	
352		At Long Point light house.	352		At Long Point light-house.	252	0	Mean low water, 1889.
364		High water, 1835.				288		High water, 1889.
398	0	Mean low water, 1835.				352		At Long Point light-house.
462	6					372		High water, 1889.
529	9				No soundings taken south of Long Point light-house in 1867.			
563	12					392	0	Mean low water, 1889.
690	13							
730	14					461	6	
748	18					576	9	
769	24					672	12	
777	30					762	18	
800	43					782	24	
829	81					792	30	
879	103					832	78	

* See illustration No. 12.

Cape Cod Harbor

Massachusetts

h showing changes in depth

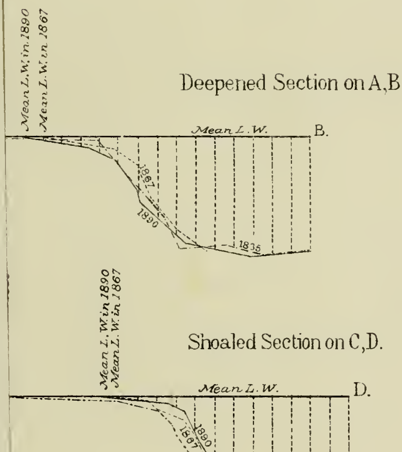
e border of House Pt. Isl. flats

1867 to 1889-90

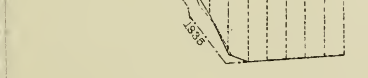
Scale of yards

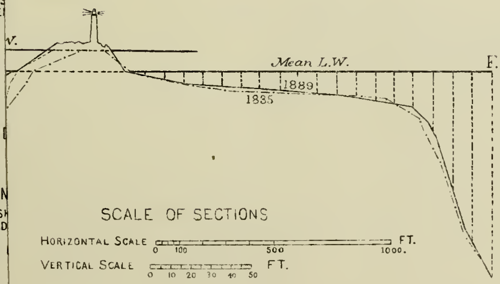
200. 300. 400 500. 1000

Deepened Section on A,B.



Shoaled Section on C,D.





NOTE : THE SHADING LINES
SHOALED OR DEEPE

DESIGNATES

" "

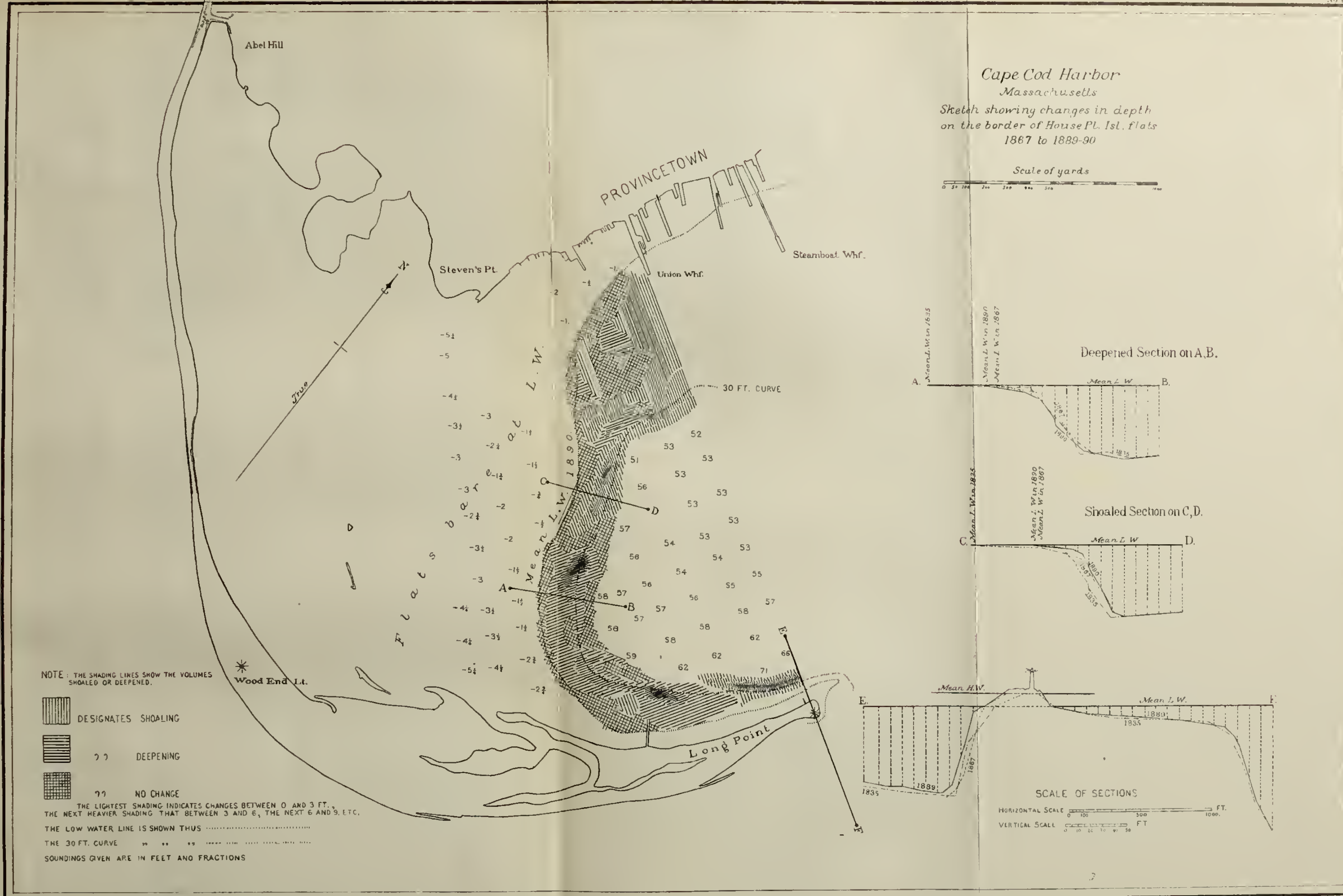
" " N

THE LIGHTEST S
THE NEXT HEAVIER SHAD
THE LOW WATER LINE
THE 30 FT. CURVE
SOUNDINGS GIVEN ARE

SCALE OF SECTIONS

HORIZONTAL SCALE 0 100 500 1000. FT.

VERTICAL SCALE 0 10 20 30 40 50 FT.


Cape Cod Harbor
Massachusetts
Sketch showing changes in depth on the border of House Pt. Isl. flats 1867 to 1889-90
Scale of yards
Abel Hill
PROVINCETOWN
Steven's Pt.
Union Whf.
Steamboat Whf.
True N
Flats bare at L. W.
Mean L. W. 1890
30 FT. CURVE
Wood End Lt.
Long Point
Deepened Section on A,B.
Mean L. W.
Shoaled Section on C,D.
Mean L. W.
Mean H.W.
Mean L. W.
SCALE OF SECTIONS
HORIZONTAL SCALE
VERTICAL SCALE
NOTE: THE SHADING LINES SHOW THE VOLUMES SHOALED OR DEEPENED.
DESIGNATES SHOALING
" DEEPENING
" NO CHANGE
THE LIGHTEST SHADING INDICATES CHANGES BETWEEN 0 AND 3 FT., THE NEXT HEAVIER SHADING THAT BETWEEN 3 AND 6, THE NEXT 6 AND 9, ETC.
THE LOW WATER LINE IS SHOWN THUS
THE 30 FT. CURVE " " "
SOUNDINGS GIVEN ARE IN FEET AND FRACTIONS

APPENDIX NO. 9—1891.

CROSS-SECTIONS OF THE SHORE OF CAPE COD, MASSACHUSETTS, BETWEEN THE CAPE COD AND LONG POINT LIGHT-HOUSES.

A report by Henry L. Marindin, Assistant.

Submitted for publication April 21, 1891.

In the publication of the following tables of cross-sections, two objects are attained. In the first place, it offers to persons interested in studying the action of the seas on the coast line, the means, in a convenient form, of comparison with former surveys ; secondarily, it insures from possible loss, by multiplication, a large amount of field and office work, which, if otherwise preserved, would be represented by records not in shape for immediate use.

The annexed tables complete the mold of the south shore of Cape Cod, and include that portion between the Cape Cod Lighthouse and the mouth of the harbor of Provincetown. They are supplementary to the series published in Appendix No. 13, Coast and Geodetic Survey Report for 1889, which included the shore between Chatham and the Cape Cod Lighthouse.

These cross-sections will average 1 in 300 metres, beginning with No. 144, at a point about 157 metres east of Highland Life-saving Station and continuing to No. 229, at the end of Long Point.

The plane of reference for the elevations is mean sea level, as derived from a series of observations of the rise and fall of the tides made at Chatham in 1887, which was found to be 40·51 feet below the Coast and Geodetic Survey Bench Mark No. IV, on Chatham North Lighthouse. This plane of reference was carried along by means of two lines of precise levels run in opposite directions. A number of bench marks were established at available points along shore, descriptions of which are appended.

The position of the origin of the cross-section can readily be platted on a projection map by using the latitude and longitude of the origin given in the table, and the direction of the section may be obtained by laying out the azimuth (which is true), also found in the table. This

azimuth is measured from the south, where it is 0° around by west to north, thence to south, where it becomes 360°.

The tables numbered 0 to 25 give the cross-sections within Cape Cod Bay, beginning at a point on High Head, Truro, and extending to the extremity of Beach Point.

Beach Point is the name of the sandy barrier dividing what was once "East Harbor" from the waters of Cape Cod Bay. While the tide still flowed through the inlet into East Harbor, Beach Point was debatable ground with reference to the causes of injury to the harbor of Provincetown, but now that this inlet is closed artificially, its importance lies in its being maintained as a beach and a means of more direct communication between Truro and Provincetown.

All the explanations given in the foregoing apply also to the tables of cross-sections for Cape Cod Bay.

The computations were made by Messrs. E. E. Haskell and Homer P. Ritter, and the preparation of the tables for publication was done by Mr. Ritter and myself jointly.

Cross-sections of the shore of Cape Cod, etc.

CROSS-SECTION No. 144.

No. 157 of 1889.

[Origin: Latitude, 42° 02′ 49″·5; longitude, 70° 04′ 20″·6; azimuth, 217° 05′.]

Distance from origin.	Height above or below mean sea level.	Remarks.
Metres.	*Feet.*	
0	66·1	
20	70·1	
40	69·2	
60	69·3	
80	71·9	
100	69·3	Bluff stake.
160	16·5	Foot of bluff.
168	15·7	
183	16·1	Edge of table.
188	13·8	Beach stake.
208	2·2	
216	— 0·8	
228	+ 5·5	
248	+ 8·6	
268	+ 0·4	
273	+ 0·0	
300	— 7·5	
400	—17·8	
500	—22·3	
600	—21·8	
700	—18·8	
800	—22·8	
900	—31·8	
1 000	—33·8	
1 060	—36·8	

CROSS-SECTION No. 145.

No. 159 of 1889.

[Origin: Latitude, 42° 02′ 50″·4; longitude, 70° 04′ 35″·8; azimuth, 217° 15′.]

Distance from origin.	Height above or below mean sea level.	Remarks.
Metres.	*Feet.*	
0	67·7	
20	69·9	
40	68·2	
60	74·3	
80	81·7	
100	86·6	
120	94·4	
140	82·7	
160	84·3	
180	77·7	
200	77·5	
224	76·1	Bluff stake.
260	22·6	
275	16·4	Foot of bluff.
280	15·2	
300	15·5	Beach stake.
306	13·3	
320	3·9	
330	0·5	
340	2·4	
360	6·9	
380	4·1	
390	— 3·3	
500	— 7·0	
600	—18·8	
700	—22·3	
800	—21·3	
900	—18·3	
1 000	—25·8	
1 100	—30·8	
1 200	—36·8	
1 300	—40·8	
1 350	—44·8	

Cross-sections of the shore of Cape Cod, etc.—Continued.

CROSS-SECTION No. 146.

No. 161 of 1889.

[Origin: Latitude, 42° 02′ 56″·6; longitude, 70° 04′ 44″·9; azimuth, 212° 37′.]

Distance from origin.	Height above or below mean sea level.	Remarks.
Metres.	*Feet.*	
0	65·8	
20	67·8	
40	70·2	
60	71·2	
80	69·0	
100	65·9	
120	70·8	
140	78·3	
160	81·0	
180	82·0	
200	81·4	
220	82·4	
240	57·6	
241	55·2	
260	37·0	
280	23·1	
300	19·0	
320	17·1	
340	14·5	Beach stake.
356	13·5	Crest of beach.
360	12·0	
366	6·9	
380	0·4	
400	— 4·5	
420	+ 2·6	
440	+ 0·1	
460	— 1·6	
471	— 2·4	
500	— 7·0	
600	—17·8	
700	—21·3	
800	—20·3	
900	—18·8	
1 000	—25·8	
1 100	—30·8	
1 200	—37·8	

CROSS-SECTION No. 147.

No. 163 of 1889.

[Origin: Latitude, 42° 03′ 05″·2; longitude, 70° 04′ 53″·2; azimuth, 212° 37′.]

Distance from origin.	Height above or below mean sea level.	Remarks.
Metres.	*Feet.*	
0	19·5	
20	18·3	
40	21.7	
60	19·4	
80	21·2	
100	20·4	
120	24·4	
140	29·4	
147	32·6	Bluff stake.
160	28·1	
180	22·0	
200	18·3	
220	14·5	Beach stake.
238	11·3	Crest of beach.
240	7·9	
260	— 1·7	
280	— 3·4	
300	— 3·8	
303	— 1·2	
320	— 1·2	
340	— 2·3	
350	— 3·0	
400	— 7·3	
500	—18·3	
600	—20·3	
700	—19·0	
800	—19·8	
900	—26·8	
1 000	—33·8	
1 070	—37·8	

Cross-sections of the shore of Cape Cod, etc.—Continued.

CROSS-SECTION No. 148.

No. 165 of 1889.

[Origin: Latitude, 42° 03′ 11″·5; longitude, 70° 05′ 03″·5; azimuth, 212° 38′.]

Distance from origin.	Height above or below mean sea level.	Remarks.
Metres.	*Feet.*	
0	5·1	
20	6·3	
40	11·3	
60	12·4	
80	13·5	
100	22·8	
114	33·2	Bluff stake.
122	25·7	
140	19·4	
160	15·9	
180	13·6	Beach stake.
200	11·8	Crest of beach.
220	8·2	
240	1·1	
253	— 3·4	
280	— 4·3	
283	+ 0·6	
300	+ 0·5	
320	— 1·2	
340	— 2·5	
350	— 3·7	
400	—11·3	
500	—21·3	
600	—19·3	
700	—15·8	
800	—21·3	
900	—27·3	
1 000	—32·8	
1 100	—36·8	

CROSS-SECTION No. 149.

No. 167 of 1889.

[Origin: Latitude, 42° 03′ 17″·2; longitude, 70° 05′ 13″·5; azimuth, 209° 45′.]

Distance from origin.	Height above or below mean sea level.	Remarks.
Metres.	*Feet.*	
0	6·1	
20	10·4	
40	19·4	
60	26·3	
80	32·9	
90	33·2	Bluff stake.
100	28·1	
104	25·3	
140	19·2	
160	14·1	
180	12·3	Beach stake.
198	10·4	Crest of beach.
200	9·5	
220	— 0·8	
240	— 5·5	
290	— 5·0	
295	— 1·5	
315	— 1·6	
335	— 1·7	
350	— 3·9	
400	—12·8	
500	—21·8	
600	—18·8	
700	—17·8	
800	—21·3	
900	—25·8	
1 000	—31·8	
1 100	—35·8	

Cross-sections of the shore of Cape Cod, etc.—Continued.

CROSS-SECTION No. 150.

No. 169 of 1889.

[Origin: Latitude, 42° 03′ 21″·3; longitude, 70° 05′ 24″·9: azimuth, 206° 56′.]

Distance from origin.	Height above or below mean sea level.	Remarks.
Metres.	*Feet.*	
0	6·0	
20	18·5	
40	25·6	
60	30·9	
80	37·9	
100	47·6	
110	52·9	Bluff stake.
120	28·8	
130	----	Foot of bluff.
140	17·0	
160	13·9	Beach stake.
180	13·2	Crest of beach.
200	1·6	
220	— 3·9	
226	— 4·4	
250	— 8·8	
300	— 1·8	
400	— 9·8	
500	—16·8	
600	—18·8	
700	—15·8	
800	—20·8	
900	—25·8	
1 000	—30·8	
1 100	—37·8	

CROSS-SECTION No. 151.

No. 171 of 1889.

[Origin: Latitude, 42° 03′ 27″·0; longitude, 70° 05′ 35″·6; azimuth, 206° 56′.]

Distance from origin.	Height above or below mean sea level.	Remarks.
Metres.	*Feet.*	
0	5·1	
20	7·5	
40	13·5	
60	20·9	
66·5	29·1	Bluff stake.
80	18·0	
100	21·5	
120	15·1	Beach stake.
140	10·5	
160	4·6	
180	— 3·5	
185	— 4·9	
200	— 6·8	
250	— 7·0	
300	— 3·1	
400	—10·8	
500	—20·3	
600	—18·3	
700	—16·3	
800	—18·8	
900	—24·8	
1 000	—30·8	
1 100	—36·8	
1 150	—39·8	

Cross-sections of the shore of Cape Cod, etc.—Continued.

CROSS-SECTION No. 152.

No. 173 of 1889.

[Origin: Latitude, 42° 03′ 28″·8; longitude, 70° 05′ 48″·7; azimuth, 206° 25′.]

Distance from origin.	Height above or below mean sea level.	Remarks.
Metres.	*Feet.*	
0	4·6	
20	6·1	
40	5·2	
60	8.3	
80	7·7	
100	20·5	
120	40·2	
140	47·4	
165	42·3	Bluff stake.
180	24·5	
200	14·9	Beach stake.
220	14·8	
240	4·5	
260	— 2·4	
300	— 7·6	
350	— 9·6	
400	— 3·6	
500	—11·8	
600	—21·3	
700	—21·8	
800	—17·3	
900	—19·3	
1 000	—24·8	
1 100	—31·8	
1 200	—35·8	

CROSS-SECTION No. 153.

No. 175 of 1889.

[Origin: Latitude. 42° 03′ 35″·4; longitude, 70° 05′ 59′ ·5; azimuth, 206° 25′.]

Distance from origin.	Height above or below mean sea level.	Remarks.
Metres.	*Feet.*	
0	3·8	
10	4·6	
30	7·7	
50	11·7	
70	16·8	
90	24·1	
95·5	28·4	Bluff stake.
110	18·3	
130	13·3	Beach stake.
150	12·8	
170	9·4	
190	1·8	
204	— 4·6	
250	— 7·6	
300	— 3·6	
400	— 7·0	
500	—19·8	
600	—22·8	
700	—19·8	
800	—19·3	
900	—21·8	
1 000	—27·3	
1 100	—33·8	
1 180	—41·8	

Cross-sections of the shore of Cape Cod, etc.—Continued.

CROSS-SECTION No. 154. No. 177 of 1889. [Origin: Latitude, 42° 03′ 34″·6; longitude, 70° 06′ 14″·7; azimuth, 206° 30′.]			CROSS-SECTION No. 155. No. 179 of 1889. [Origin: Latitude, 42° 03′ 36″·3; longitude, 70° 06′ 27″·0; azimuth, 204° 25′.]		
Distance from origin.	Height above or below mean sea level.	Remarks.	Distance from origin.	Height above or below mean sea level.	Remarks.
Metres.	*Feet.*		*Metres.*	*Feet.*	
0	4·2		0	3·4	
20	7·3		20	13·2	
40	13·4		40	28·0	
50	23·1		60	30·6	
60	11·7		80	25·4	
80	6·5		100	36·4	
100	8·2		120	35·5	
120	14·5		127	38·6	
140	27·1		140	19·9	
150	41·9		160	12·6	
160	47·9		180	13·0	
180	29·8		200	16·9	
200	25·0		220	22·6	
220	25·0		240	17·3	
240	26·4		260	11·0	
260	34·5	Bluff stake.	280	10·3	
280	16·1		300	15·4	
300	13·2	Beach stake	320	17·0	
320	10·1		340	18·5	
325	10·1	Crest of beach.	351·5	22·5	Bluff stake.
340	1·0		360	16·2	
354	— 4·7		380	10·6	Beach stake; crest of beach.
400	— 5·6		400	3·8	
500	— 9·8		420	— 5·0	
600	—10·8		500	— 9·8	
700	—20·3		600	— 9·3	
800	—24·8		700	—10·8	
900	—23·8		800	—21·3	
1 000	—18·8		900	—23·3	
1 100	—21·8		1 000	—21·3	
1 200	—27·8		1 100	—14·8	
1 300	—33·8		1 200	—22·3	
1 360	—40·8		1 300	—26·8	
			1 400	—32·8	
			1 500	—40·8	

Cross-sections of the shore of Cape Cod, etc.—Continued.

CROSS-SECTION No. 156.

No. 181 of 1889.

[Origin: Latitude, 42° 03′ 36″·4; longitude, 70° 06′ 41″·3; azimuth, 204° 30′.]

Distance from origin.	Height above or below mean sea level.	Remarks.
Metres.	*Feet.*	
0	2·3	
10	3·3	
30	3·4	
50	9·0	
70	16·7	
90	24·0	
97	27·0	
110	11·9	
130	4·2	
150	3·6	
170	5·6	
190	5·5	
210	3·7	
230	8·2	
250	27·1	
270	21·6	
290	8·8	
310	7·3	
330	5·3	
350	4·8	
370	6·4	
390	7·1	
410	6·3	
430	23·5	
450	37·2	
470	48·9	
490	15·1	
510	15·6	Bluff stake.
514	14·4	Foot of bluff.
516	8·8	Beach stake.
520	6·2	
530	0·7	
543	— 4·5	
600	— 7·6	
700	— 8·0	
800	— 6·6	
900	—15·8	
1 000	—25·8	
1 100	—30·8	
1 200	—20·3	
1 300	—19·8	
1 400	—24·8	
1 500	—29·8	
1 575	—34·8	

CROSS-SECTION No. 157.

No. 183 of 1889.

[Origin: Latitude, 42° 03′ 39″·4; longitude, 70° 06′ 53″·3; azimuth, 205° 10′.]

Distance from origin.	Height above or below mean sea level.	Remarks.
Metres.	*Feet.*	
0	1·2	Edge of marsh.
20	4·8	
40	15·4	
50	21·3	Crest of ridge.
60	14·9	
80	10·9	
100	7·5	
120	1·1	
140	1·1	
160	1·1	
180	3·9	
200	1·2	
220	2·1	
240	5·6	
260	5·2	
280	2·2	
300	2·3	
320	3·2	
340	2·5	
360	4·0	
380	4·2	
400	5·4	
420	6·5	
440	4·5	
460	8·3	
474	11·8	Bluff stake.
480	9·0	
500	10·8	
520	11·1	
540	11·5	Beach stake.
560	8·8	
575	7·3	Crest of beach.
580	5·4	
599	— 2·6	
700	—10·3	
750	—11·8	
800	— 8·8	
900	—12·3	
1 000	—22·3	
1 100	—25·8	
1 200	—24·3	
1 300	—23·3	
1 400	—19·3	
1 500	—22·3	
1 600	—26·8	
1 700	—31·8	
1 800	—35·8	

Cross-sections of the shore of Cape Cod, etc.—Continued.

CROSS-SECTION No. 158.

No. 185 of 1889.

[Origin: Latitude, 42° 03′ 42″·8 ; longitude, 70° 07′ 04″·8 ; azimuth, 201° 55′.]

Distance from origin.	Height above or below mean sea level.	Remarks.
Metres.	*Feet.*	
0	0·9	Edge of marsh.
10	2·3	
30	3·4	
50	4·2	
70	7·2	
90	14·9	
110	17·1	
130	23·8	
150	22·2	
170	2·6	
190	0·7	
210	— 2·4	
230	19·7	
250	15·2	
270	9·7	
290	7·6	
310	1·5	
330	3·6	
350	11·9	
370	4·1	
390	4·1	
410	4·1	
430	6·0	
450	6·4	
470	8·2	
490	14·7	
510	34·2	
536	14·4	
550	10·0	Beach stake.
558	8·2	Crest of beach.
570	3·6	
573	2·0	
600	— 5·8	
700	—10·3	
750	—14·8	
800	— 6·8	
900	—11·3	
1 000	—21·3	
1 100	—26·8	
1 200	—30·3	
1 300	—23·3	
1 400	—19·8	
1 500	—23·8	
1 600	—28·8	
1 700	—32·8	
1 800	—38·8	
1 850	—39·8	

CROSS-SECTION No. 159.

No. 187 of 1889.

[Origin: Latitude, 42° 03′ 44″·2 ; longitude, 70° 07′ 17″·8 ; azimuth, 201° 55′.]

Distance from origin.	Height above or below mean sea level.	Remarks.
Metres.	*Feet.*	
0	3·7	
20	4·9	
40	13·2	
47	17·4	
80	25·2	
91	31·0	
100	34·6	
120	41·4	
140	44·2	
160	45·9	
180	47·8	
200	46·7	
220	54·4	
240	54.6	
260	41·9	
280	40.1	
300	32.2	
320	28·0	
340	27·6	
360	30·5	
380	25·1	
400	24·7	
420	25·2	
440	35·9	
460	48·9	
464	47·8	
480	37·4	
483	33·4	
500	16·9	
520	12·9	
540	17·4	
560	13·9	
580	25·9	
596	33·4	Bluff stake.
600	24·6	
608	15·6	Foot of bluff.
620	13·1	Beach stake.
630	12·6	Crest of beach.
640	4·5	
659	— 3·7	
700	— 8·0	
800	— 7·0	
900	— 9·8	
1 000	—12·8	
1 100	—22·8	
1 200	—29·3	
1 300	—25·8	
1 400	—24·8	
1 500	—24·8	
1 600	—23·8	
1 700	—27·8	
1 800	—33·8	

Cross-sections of the shore of Cape Cod, etc.—Continued.

CROSS-SECTION No. 160.

No. 189 of 1889.

[Origin: Latitude, 42° 03′ 50″·2; longitude, 70° 07′ 28″·7; azimuth, 202° 35′.]

Distance from origin.	Height above or below mean sea level.	Remarks.
Metres.	*Feet.*	
0	6·1	Near edge of marsh.
20	11·0	
40	23·8	
60	22·5	
80	16·4	
100	14·9	
120	11·7	
140	18·0	
160	11·1	
180	6·0	
200	5·1	
220	3·7	
240	6·2	
260	4·5	
280	4·8	
300	4·0	
320	5·1	
340	4·8	
360	8·1	
380	14·2	
400	19·2	
420	17·6	
440	14·9	
460	32·4	

CROSS-SECTION No. 160—Continued.

No. 189 of 1889.

[Origin: Latitude, 42° 03′ 50″·2; longitude. 70° 07′ 28″·7; azimuth, 202° 35′.]

Distance from origin.	Height above or below mean sea level.	Remarks.
Metres.	*Feet.*	
465	37·6	Top of ridge.
480	32·2	
500	34·0	
520	36·6	
525	37·9	Bluff stake.
540	12·8	Beach stake and foot of bluff.
560	8·7	
580	7·8	
592	7·4	Crest of beach.
600	3·9	
614	— 2·1	
700	— 9·8	
800	— 7·3	
900	— 6·8	
1 000	—13·8	
1 100	—18·8	
1 200	—24·8	
1 300	—25·8	
1 400	—24·3	
1 500	—21·3	
1 600	—21·3	
1 700	—24·8	
1 800	—32·8	
1 850	—35·8	

Cross-sections of the shore of Cape Cod, etc.—Continued.

CROSS-SECTION No. 161. No. 191 of 1889. [Origin: Latitude, 42° 03′ 48″·9; longitude, 70° 07′ 43″·5; azimuth, 202° 15′.]			CROSS-SECTION No. 161—Continued. No. 191 of 1889. [Origin: Latitude, 42° 03′ 48″·9; longitude, 70° 07′ 43″·5; azimuth, 202° 15′.]		
Distance from origin.	Height above or below mean sea level.	Remarks.	Distance from origin.	Height above or below mean sea level.	Remarks.
Metres.	*Feet.*		*Metres.*	*Feet.*	
0	2·9		530	6·9	
10	4·3		550	17·0	
30	2·7		570	20·0	
50	4·6		590	16·6	
70	2·6		610	18·7	
90	3·6		630	8·5	
110	4·3		650	9·6	
130	4·5		670	13·5	
150	6·4		690	14·3	
170	8·5		710	10·0	Beach stake.
190	16·8		730	8·8	
210	25·9		750	— 0·3	
230	35·2		800	— 8·3	
250	28·4		900	—13·8	
270	24·3		1 000	—10·8	
290	22·2		1 100	— 8·8	
310	18·4		1 200	—19·8	
330	20·6		1 300	—19·8	
350	20·8		1 400	—21·8	
370	18·5		1 500	—26·8	
390	5·5		1 600	—29·8	
410	4·4		1 700	—31·8	
430	4·0		1 800	—23·8	
450	3·5		1 900	—25·3	
470	3·8		2 000	—31·8	
490	3·8		2 100	—41·8	
510	4·5				

Cross-sections of the shore of Cape Cod, etc.—Continued.

CROSS-SECTION No. 162.

No. 193 of 1889.

[Origin: Latitude, 42° 03′ 54″·1; longitude, 70° 07′ 55″·2; azimuth, 205° 25′.]

Distance from origin.	Height above or below mean sea level.	Remarks.
Metres.	*Feet.*	
0	7·3	
20	12·3	
40	19·1	
60	27·1	
80	34·6	
100	48·4	
120	36·1	
140	26·2	
160	21·3	
180	18·2	
200	15·5	
220	12·8	
240	9·9	
260	6·8	
280	4·5	
300	3·4	
320	3·3	
340	5·6	
360	5·7	
380	5·9	
400	8·2	
420	17·5	
440	31·2	
451	42·7	
454	40·6	
460	33·3	

CROSS-SECTION No. 162—Continued.

No. 193 of 1889.

[Origin: Latitude, 42° 03′ 54″·1; longitude, 70° 07′ 55″·2; azimuth, 205° 25′.]

Distance from origin.	Height above or below mean sea level.	Remarks.
Metres.	*Feet.*	
480	28·1	
500	32·4	
512	39·4	Top of ridge.
520	14·8	
540	20·8	
557	37·4	Bluff stake.
580	4·4	
600	6·6	
620	10·3	
640	10·2	
660	7·0	Beach stake.
675	0·1	
700	— 6·3	
800	— 9·8	
900	—11·3	
1 000	— 9·8	
1 100	— 9·8	
1 200	—16·8	
1 300	—26·8	
1 400	—32·8	
1 500	—29·8	
1 600	—29·8	
1 700	—28·8	
1 800	—24·8	
1 900	—30·8	
1 950	—37·8	

Cross-sections of the shore of Cape Cod, etc.—Continued.

CROSS-SECTION No. 163.

No. 195 of 1889.

[Origin: Latitude, 42° 03′ 54″·9; longitude, 70° 08′ 07″·6; azimuth, 200° 20′.]

Distance from origin.	Height above or below mean sea level.	Remarks.
Metres.	*Feet.*	
0	15·7	
20	21·7	
40	32·1	
60	38·5	
80	45·4	
100	52·7	
120	63·2	
140	50·9	
160	45·6	
180	42·2	
200	39·0	
220	35·4	
240	31·4	
260	26·8	
280	21·6	
300	17·3	
320	14·7	
340	19·9	
360	23·2	
380	6·1	
400	3·5	
420	9·6	
440	7·3	
460	6·5	
480	7·0	
500	11·7	
520	11·8	
540	3·2	
560	7·8	

CROSS-SECTION No. 163—Continued.

No. 195 of 1889.

[Origin: Latitude, 42° 03′ 54″·9; longitude, 70° 08′ 07″·6; azimuth, 200° 20′.]

Distance from origin.	Height above or below mean sea level.	Remarks.
Metres.	*Feet.*	
580	11·0	
600	2·6	
620	6·6	
632	20·6	Bluff stake.
640	12·6	
660	6·6	
680	11·0	
700	12·0	
720	11·7	
740	10·6	Beach stake.
747	9·5	Crest of beach.
760	2·8	
765	0·2	
800	— 5·8	
900	— 8·3	
1 000	— 7·3	
1 100	—11·8	
1 200	— 9·8	
1 300	—20·8	
1 400	—25·8	
1 500	—27·8	
1 600	—25·8	
1 700	—24·8	
1 800	—26·3	
1 900	—21·8	
2 000	—23·8	
2 100	—31·8	
2 175	—41·8	

Cross-sections of the shore of Cape Cod, etc.—Continued.

CROSS-SECTION No. 164.

No. 197 of 1889.

[Origin: Latitude, 42° 04′ 12″·5; longitude, 70° 08′ 12″·2, azimuth, 198° 40′.]

Distance from origin.	Height above or below mean sea level.	Remarks.
Metres.	*Feet.*	
0	8·8	
20	11.6	
40	9·6	
60	2·1	
80	5·2	Inner edge of cranberry bog.
100	2·5	In cranberry bog.
120	2·6	In cranberry bog.
140	3·2	Outer edge of cranberry bog.
160	7·7	
180	20·0	
200	29·2	
220	39·6	
228	42·8	
243	10·6	Foot of bluff.
260	7·8	Beach stake.
269	7·5	Crest of beach.
280	2·3	
286	— 0·4	
300	— 3·8	
400	—10·3	
500	—14·3	
600	— 9·0	
700	—12·3	
800	—11·3	
900	—23·8	
1 000	—25·8	
1 100	—24·8	
1 200	—24·8	
1 300	—24·8	
1 400	—21·8	
1 450	—19·3	
1 500	—21·8	
1 600	—30·8	
1 700	—34·0	
1 800	—36·8	

CROSS-SECTION No. 165.

No. 199 of 1889.

[Origin: Latitude, 42° 04′ 15″·1; longitude, 70° 08′ 25″·0; azimuth, 199° 00′.]

Distance from origin.	Height above or below mean sea level.	Remarks.
Metres.	*Feet.*	
0	16·4	
20	12·2	
40	22·4	
60	25·2	
80	25·4	
100	25·0	
120	30·3	
140	20·0	
160	14·2	
180	8·0	
200	7·0	
220	13·0	
240	38·7	
249·5	45·4	Bluff stake.
268	11·0	
280	3·8	Beach stake.
293	2·4	
300	— 2·8	
400	— 9·8	
500	—11·3	
600	—12·3	
700	—13·8	
800	— 9·0	
900	—19·8	
1 000	—25·8	
1 100	—24·8	
1 200	—22·8	
1 300	—22·8	
1 400	—20·8	
1 500	—23·8	
1 600	—29·3	
1 700	—33·8	
1 800	—36·8	

Cross-sections of the shore of Cape Cod, etc.—Continued.

CROSS-SECTION No. 166.

No. 201 of 1889.

[Origin: Latitude, 42° 04′ 01″·3; longitude, 70° 08′ 44″·9; azimuth, 198° 20′.]

Distance from origin.	Height above or below mean sea level.	Remarks.
Metres.	*Feet.*	
0	1·4	Edge of marsh.
12	9·4	
32	24·1	
52	33·6	
72	56·7	
92	53·7	
112	38·3	
132	40·9	
152	45·6	
172	49·2	
192	52·3	
212	54·1	
232	54·7	
252	53·7	
272	51·5	
292	48·0	
312	45·0	
332	45·4	
352	41·7	
372	37·4	
392	28·8	
412	24·9	
432	28·0	
452	35·6	
472	33·8	
492	24·4	
512	9·4	
532	3·4	
552	3·8	
572	10·8	
592	21·4	
612	23·9	

CROSS-SECTION No. 166—Continued

No. 201 of 1889.

[Origin: Latitude, 42° 04′ 01″·3; longitude, 70° 08′ 44″·9; azimuth, 198° 20′.]

Distance from origin.	Height above or below mean sea level.	Remarks.
Metres.	*Feet.*	
632	20·2	
652	8·7	
672	6·9	
692	5·4	
712	3·9	
732	3·9	
752	6·2	
772	15·6	
792	14·9	
812	24·6	
832	37·9	
852	15·5	Beach stake, foot of bluff.
872	10·1	
889	9·6	Crest of beach.
892	7·8	
912	— 1·5	
1 000	—13·8	
1 100	— 8·3	
1 200	—11·3	
1 300	—14·8	
1 400	—10·8	
1 500	—21·8	
1 600	—24·8	
1 700	—23·8	
1 800	—21·8	
1 900	—20·8	
2 000	—24·8	
2 100	—31·8	
2 200	—33·8	
2 300	—36·8	

Cross-sections of the shore of Cape Cod, etc.—Continued.

CROSS-SECTION No. 167.

No. 203 of 1889.

[Origin: Latitude, 42° 04′ 23″.1; longitude, 70° 08′ 48″·6; azimuth, 198° 40′.]

Distance from origin.	Height above or below mean sea level.	Remarks.
Metres.	*Feet.*	
0	25·7	
20	36·6	
40	30·4	
60	39·3	
80	34·0	
100	23·7	
120	5·1	
140	3·8	
160	20·4	
180	33·8	
198·5	31·7	Bluff stake.
220	20·1	Beach stake.
240	11·1	
260	9·4	
280	8·8	Crest of beach.
288	5·5	
300	— 3·3	
400	— 8·8	
500	—12·3	
600	—14·3	
700	—13·8	
800	—11·8	
900	—22·8	
1 000	—26·8	
1 100	—23·3	
1 200	—21·3	
1 300	—23·3	
1 400	—27·3	
1 500	—29·3	
1 600	—34·3	
1 700	—37·3	

CROSS-SECTION No. 168.

No. 205 of 1889.

[Origin: Latitude, 42° 04′ 26″·9; longitude, 70° 09′ 01″·0; azimuth, 199° 00′.]

Distance from origin.	Height above or below mean sea level.	Remarks.
Metres.	*Feet.*	
0	10·4	
20	3·2	
40	4·5	
60	19·8	
80	5·2	
100	3·6	
120	15·5	
140	13·3	
160	25·1	
181	32·4	Bluff stake.
200	19·6	Beach stake.
220	14·0	
240	10·3	
260	10·1	Crest of beach.
264	6·5	
300	— 8·0	
400	—14·8	
500	— 8·6	
600	—11·8	
700	—15·3	
750	— 7·6	
800	—11·3	
900	—25·8	
1 000	—31·8	
1 100	—32·8	
1 200	—21·8	
1 300	—23·8	
1 400	—28·3	
1 500	—31·8	
1 600	—38·8	

Cross-sections of the shore of Cape Cod, etc.—Continued.

CROSS-SECTION No. 169.

No. 207 of 1889.

[Origin: Latitude, 42° 04′ 29″·4; longitude, 70° 09′ 13″·4; azimuth, 198° 50′.]

Distance from origin.	Height above or below mean sea level.	Remarks.
Metres.	*Feet.*	
0	5·8	
20	5·4	
40	5·0	
60	3·2	
80	10·8	
Stone.	24·7	Truro corner No. 7.
100	21·9	
120	21·8	
140	26·1	
160	30·1	
180	31·1	
194	32·7	Bluff stake.
200	25·9	
220	19·9	Beach stake.
240	13·4	
260	11·6	
280	9·9	Crest of beach.
287	8·0	
300	— 3·8	
400	—11·8	
500	—11·8	
600	— 8·6	
700	—13·3	
750	— 8·3	
800	—15·8	
900	—23·8	
1 000	—28·3	
1 100	—28·3	
1 200	—21·8	
1 300	—21·3	
1 400	—28·8	
1 500	—34·8	
1 600	—35·8	
1 700	—38·8	
1 800	—41·8	

CROSS-SECTION No. 170.

No. 209 of 1889.

[Origin: Latitude, 42° 04′ 31″·8; longitude, 70° 09′ 25″·8; azimuth, 196° 50′.]

Distance from origin.	Height above or below mean sea level.	Remarks.
Metres.	*Feet.*	
0	8·5	
20	6·7	
40	4·3	
60	5·1	
80	18·2	
100	19·5	
120	21·3	
140	19·7	
160	23·5	
180	24·7	
200	29·2	
212	33·0	Bluff stake.
224	17·7	Foot of bluff.
240	13·0	Beach stake.
260	11·5	
280	10·2	Crest of beach.
300	1·6	
400	—14·8	
500	—11·3	
600	— 8·8	
700	—12·3	
800	—12·8	
900	—23·8	
1 000	—27·3	
1 100	—29·8	
1 200	—27·8	
1 300	—21·3	
1 400	—24·8	
1 500	—33·8	
1 600	—36·8	
1 700	—39·8	
1 800	—42·8	

Cross-sections of the shore of Cape Cod, etc.—Continued.

CROSS-SECTION No. 171.

No. 211 of 1889.

[Origin: Latitude, 42° 04′ 34″·2; longitude, 70° 09′ 38″·0; azimuth, 194° 55′.]

Distance from origin.	Height above or below mean sea level.	Remarks.
Metres.	*Feet.*	
0	21·7	
20	5·2	
40	13·2	
60	18·6	
80	17·8	
100	14.2	
120	12·6	
140	18·9	
160	24·6	
180	22·8	
200	29·4	
212	34·1	Bluff stake.
220	20·6	
240	11·6	Beach stake.
260	9·3	
278	8·6	Crest of beach.
300	1·1	
400	—14·8	
500	—16·3	
600	— 8·8	
700	— 9·8	
800	—16·3	
900	—22·3	
1 000	—24·3	
1 100	—27·8	
1 200	—29·8	
1 300	—20·8	
1 400	—24·8	
1 500	—33·8	
1 600	—39·8	
1 700	—43·8	
1 800	—45·8	

CROSS-SECTION No. 172.

No. 213 of 1889.

[Origin: Latitude, 42° 04′ 37″·9; longitude, 70° 09′ 50″·1; azimuth, 194° 30′.]

Distance from origin.	Height above or below mean sea level.	Remarks.
Metres.	*Feet.*	
0	23·3	
20	30·8	
40	29·4	
60	29·7	
80	24·8	
100	22·1	
120	24·8	
140	31·2	
160	34·3	
175	31·1	Bluff stake.
184	11·1	Foot of bluff.
200	10·3	
205	10·3	Crest of beach.
240	3·3	
248	— 1.9	
300	—13·3	
400	—16·8	
500	—16·3	
600	— 9·6	
700	— 9·8	
800	—17·8	
900	—23·8	
1 000	—27·8	
1 100	—30·8	
1 200	—25·8	
1 300	—20·8	
1 400	—29·8	
1 500	—39·8	
1 600	—42·8	

Cross-sections of the shore of Cape Cod, etc.—Continued.

CROSS-SECTION No. 173.

No. 215 of 1889.

[Origin: Latitude, 42° 04′ 39″·2; longitude, 70° 10′ 03″·6; azimuth, 194° 35′.]

Distance from origin.	Height above or below mean sea level.	Remarks.
Metres.	*Feet.*	
0	8·6	
20	19·6	
40	23·4	
60	5·9	
80	5·2	
100	4·8	
120	6·9	
140	12·3	
160	36·7	
180	29·1	
200	29·9	
209	29·2	Bluff stake.
220	17·6	
240	10·4	Beach stake.
260	8·8	Crest of beach.
280	0·9	
285	— 1·6	
300	— 8·8	
400	—12·8	
500	—14·8	
600	—10·8	
700	—14·3	
800	—14·3	
900	—24·3	
1 000	—26·3	
1 100	—28·3	
1 200	—28·3	
1 300	—20·3	
1 400	—27·8	
1 500	—36·8	
1 600	—39·8	
1 700	—44·8	

CROSS-SECTION No. 174.

No. 217 of 1889.

[Origin: Latitude, 42° 04′ 41″·6; longitude, 70° 10′ 16″·1; azimuth, 194° 35′.]

Distance from origin.	Height above or below mean sea level.	Remarks.
Metres.	*Feet.*	
0	15·6	
20	19·4	
40	15·7	
60	31·3	
80	37·5	
100	37·6	
120	36·7	
141	51·4	
160	37·4	
180	31·7	
200	23·1	
220	13·1	Foot of bluff.
240	10·7	
260	8·9	
280	10·7	Crest of beach.
300	2·4	
305	0.5	
400	—10·3	
500	—15·3	
600	—13·8	
700	—16·3	
800	—13·8	
900	—22·3	
1 000	—25·8	
1 100	—27·3	
1 200	—26·8	
1 300	—21·8	
1 400	—31·8	
1 500	—37·8	
1 600	—42·3	
1 700	—48·8	

Cross-sections of the shore of Cape Cod, etc.—Continued.

CROSS-SECTION No. 175.

No. 219 of 1889.

[Origin: Latitude, 42° 04′ 44″·7; longitude, 70° 10° 27″·2; azimuth, 187° 50′.]

Distance from origin.	Height above or below mean sea level.	Remarks.
Metres.	*Feet.*	
0	51·5	
20	56·6	
40	65·7	
60	55·8	
80	56·8	
98	45·4	Bluff stake.
100	41·3	
120	28·3	
140	18·7	
160	15·3	
180	12·4	
200	9·8	
220	6·6	Beach stake.
240	9·2	
251	10·2	Crest of beach.
260	4·3	
265	1·9	
300	— 9·8	
400	—15·8	
500	—12·3	
600	—14·3	
700	—14·8	
800	—16·8	
900	—23·8	
1 000	—24·8	
1 100	—25·8	
1 200	—22·3	
1 300	—30·8	
1 400	—38·8	
1 500	—40·8	
1 600	—47·8	
1 650	—50·8	

CROSS-SECTION No. 176.

No. 221 of 1889.

[Origin: Latitude, 42° 04′ 44″·6; longitude, 70° 10′ 39″·4; azimuth, 182° 00′.]

Distance from origin.	Height above or below mean sea level.	Remarks.
Metres.	*Feet.*	
0	5·0	
20	4·1	
40	4·7	
60	5·8	
80	11·2	
100	23·4	
120	38·2	Bluff stake.
140	24·3	
160	19·5	
180	14·1	
200	11·4	
220	8·2	Beach stake.
240	6·0	
260	8·3	
274	9·8	Crest of beach.
289	3·8	
300	— 3·2	
400	—11·8	
500	—18·3	
600	—12·8	
700	—14·3	
800	—17·8	
900	—23·8	
1 000	—24·8	
1 100	—26·8	
1 200	—24·8	
1 300	—28·8	
1 400	—33·8	
1 500	—41·8	

Cross-sections of the shore of Cape Cod, etc.—Continued.

CROSS-SECTION No. 177. No. 223 of 1889. [Origin: Latitude, 42° 04′ 45″·0; longitude, 70° 10′ 52″·2; azimuth, 182° 00′.]			CROSS-SECTION No. 178. No. 225 of 1889. [Origin: Latitude, 42° 04′ 45″·4; longitude, 70° 11′ 05″·3; azimuth, 182° 00′.]		
Distance from origin.	Height above or below mean sea level.	Remarks.	Distance from origin.	Height above or below mean sea level.	Remarks.
Metres.	*Feet.*		*Metres.*	*Feet.*	
0	11·5		0	21·4	
20	13·6		20	10·9	
40	6·3		40	4·0	
60	6·6		60	5·0	
80	5·5		80	5·4	
100	7·2		100	5·2	
120	22·2		120	7·5	
140	32·8		140	10·8	
156	41·2	Bluff stake.	160	22·6	
180	28·6		180	32·3	
200	12·7		186	37·6	Bluff stake.
220	6·0		200	16·3	
240	5·6		220	4·4	Beach stake.
260	7·9		240	1·2	
270	7·4	Crest of beach.	260	7·5	Crest of beach.
280	4·5		280	1·8	
284	1·1		300	— 5·3	
300	— 3·4		400	— 9·3	
400	—11·8		500	—13·3	
500	—17·8		600	—12·6	
600	—18·8		650	—17·8	
700	— 9·8		700	—16·8	
800	—19·3		800	—15·8	
900	—24·8		900	—24·8	
1 000	—27·8		1 000	—28·8	
1 100	—27·8		1 100	—26·8	
1 200	—27·8		1 200	—24·8	
1 300	—32·8		1 300	—28·8	
1 400	—37·8		1 400	—35·8	
1 500	—40·8		1 500	—39·8	
1 600	—47·8		1 600	—47·8	
			1 700	—53·8	

Cross-sections of the shore of Cape Cod, etc.—Continued.

CROSS-SECTION No. 179. No. 227 of 1889. [Origin: Latitude, 42° 04′ 44″·9; longitude, 70° 11′ 18″·4; azimuth, 182° 00′.]			CROSS-SECTION No. 180. No. 229 of 1889. [Origin: Latitude, 42° 04′ 45″·9; longitude, 70° 11′ 31″·8; azimuth, 182° 50′.]		
Distance from origin.	Height above or below mean sea level.	Remarks.	Distance from origin.	Height above or below mean sea level.	Remarks.
Metres.	*Feet.*		*Metres.*	*Feet.*	
0	25·8	Crest of rigde.	0	15·1	
20	20·0		20	5·5	
40	20·9		40	6·4	
60	18·8		60	5·0	
80	7·9		80	3·8	
100	7·9		100	3·6	
120	14·4		120	6·3	
140	9·2		140	7·5	
160	21·2		160	22·5	
180	19·9		180	24·8	
200	28·4		202	31·5	Bluff stake.
204	28·3	Bluff stake.	220	9·4	Beach stake.
220	15·4		230	8·5	Crest of beach.
240	7·2	Beach stake.	240	4·0	
249	3·0		300	— 9·8	
300	— 8·0		400	—11·8	
400	—12·3		500	—12·8	
500	— 9·3		600	—15·8	
600	—13·8		700	—20·8	
700	—18·3		800	—12·8	
800	—11·8		900	—24·8	
900	—21·8		1 000	—27·8	
1 000	—25·3		1 100	—28·8	
1 100	—28·8		1 200	—27·8	
1 200	—28·3		1 300	—28·8	
1 300	—29·8		1 400	—33·8	
1 400	—33·3		1 500	—39·3	
1 500	—40·8		1 600	—46·8	
1 600	—46·8				
1 700	—56·8				

Cross-sections of the shore of Cape Cod, etc.—Continued.

CROSS-SECTION No. 181. No. 231 of 1889. [Origin: Latitude, 42° 04′ 46″·7; longitude, 70° 11′ 44″·7; azimuth, 181° 50′.]			CROSS-SECTION No. 182. No. 233 of 1889. [Origin: Latitude, 42° 04′ 46″·6; longitude, 70° 11′ 57″·9; azimuth, 181° 56′.]		
Distance from origin.	Height above or below mean sea level.	Remarks.	Distance from origin.	Height above or below mean sea level.	Remarks.
Metres.	*Feet.*		*Metres.*	*Feet.*	
0	17·4		0	9·7	
20	11·2		20	4·9	
40	7·5		40	4·2	
60	5·5		60	3·8	
80	7·7		80	4·9	
100	10·4		100	4·4	
120	11·5		120	5·1	
140	25·2		140	5·7	
160	31·8		160	15·8	
180	30·7		180	24·3	
191	33·3	Bluff stake.	182	33·6	Bluff stake.
200	12·4	Beach stake.	200	16·0	
220	9·9		220	13·3	Beach stake.
225	10·0	Crest of beach.	240	7·7	
236	4·7		260	9·4	
300	—10·3		271	9·5	Crest of beach.
400	—12·8		280	3·7	
500	—13·3		300	— 4·6	
600	—15·3		400	—10·8	
700	—19·3		500	—14·0	
800	—15·8		600	—13·8	
900	—26·8		700	—17·8	
1 000	—34·8		800	—12·0	
1 100	—30·8		900	—21·8	
1 200	—32·8		1 000	—29·8	
1 300	—30·8		1 100	—32·8	
1 400	—35·8		1 200	—29·8	
1 500	—43·8		1 300	—29·8	
1 550	—50·8		1 400	—34·8	
			1 500	—41·8	
			1 600	—57·8	

Cross-sections of the shore of Cape Cod, etc.—Continued.

CROSS-SECTION No. 183. No. 235 of 1889. [Origin: Latitude, 42° 04′ 47″·2; longitude, 70° 12′ 10″·1; azimuth, 182° 00′.]			CROSS-SECTION No. 184. No. 237 of 1889. [Origin: Latitude, 42° 04′ 45″·8; longitude, 70° 12′ 21″·6; azimuth, 172° 40′.]		
Distance from origin.	Height above or below mean sea level.	Remarks.	Distance from origin.	Height above or below mean sea level.	Remarks.
Metres.	*Feet.*		*Metres.*	*Feet.*	
0	23·8		0	24·1	
10	14·3		20	12·7	
30	6·0		40	11·0	
50	4·0		60	6·1	
70	4·5		80	4·6	
90	5·2		100	5·9	
110	7·0		120	4·1	
130	18·5		140	5·2	
150	35·1		160	12·4	
170	35·6		180	31·6	
179	35·8	Bluff stake.	200	28·0	
190	18·8		208	27·1	Bluff stake.
210	8·3	Beach stake.	220	7·2	
230	7·5		240	4·6	Beach stake.
250	10·2	Crest of beach.	260	7·3	
262	3·1		267	8·0	Crest of beach.
300	— 8·3		280	2·2	
400	—12·8		300	— 3·8	
500	—17·3		400	—10·8	
600	—15·3		500	—15·3	
700	—17·3		600	—20·8	
800	—14·3		700	—13·8	
900	—24·8		800	—12·8	
1 000	—30·8		900	—25·8	
1 100	—33·3		1 000	—31·8	
1 200	—28·8		1 100	—29·8	
1 300	—32·8		1 200	—31·8	
1 400	—42·8		1 300	—42·8	
			1 400	—55·8	
			1 500	—66·8	

Cross-sections of the shore of Cape Cod, etc.—Continued.

CROSS-SECTION No. 185.

No. 239 of 1889.

[Origin: Latitude, 42° 04′ 44″·4; longitude, 70° 12′ 34″·6; azimuth, 172° 40′.]

Distance from origin.	Height above or below mean sea level.	Remarks.
Metres.	*Feet.*	
0	18·0	
20	17·8	
40	7·5	
60	8·8	
80	8·4	
100	6·3	
120	25·3	
140	26·2	
160	29·1	
180	34·4	
200	31·3	
209	31·0	Bluff stake.
220	13·6	
240	8·3	
248	9·0	Crest of beach.
259	— 0·1	
300	— 6·8	
400	— 8·8	
500	—11·8	
600	—18·3	
700	—19·8	
800	—11·3	
900	—22·8	
1 000	—28·8	
1 100	—31·8	
1 200	—33·8	
1 300	—54·8	
1 380	—87·8	

CROSS SECTION No. 186.

No. 241 of 1889.

[Origin: Latitude, 42° 04′ 44″·1; longitude, 70° 12′ 47″·7; azimuth, 172° 20′.]

Distance from origin.	Height above or below mean sea level.	Remarks.
Metres.	*Feet.*	
0	19·0	
10	12·1	
30	15·4	
50	5·9	
70	5·6	
90	7·8	
110	19·2	
130	34·4	
150	36·1	
170	26·9	
175	28·3	Bluff stake.
190	9·4	
210	7·9	Beach stake.
222	8·4	Crest of beach.
233	— 1·9	
300	— 9·8	
400	—11·8	
500	—10·3	
600	—14·8	
700	—19·8	
800	—11·8	
900	—23·8	
1 000	—28·3	
1 100	—30·8	
1 200	—43·8	

Cross-sections of the shore of Cape Cod, etc.—Continued.

CROSS-SECTION No. 187.

No. 243 of 1889.

[Origin: Latitude, 42° 04′ 41″·8; longitude, 70° 13′ 00″·5; azimuth, 172° 10′.]

Distance from origin.	Height above or below mean sea level.	Remarks.
Metres.	*Feet.*	
0	10·1	Slope of ridge.
20	4·3	
40	4·5	
60	8·6	
80	4·8	
100	7·6	
120	17·3	
140	31·4	
160	26·0	
180	23·4	
190	21·8	Bluff stake.
200	18·0	
220	13·4	
240	9·9	
257	10·0	Crest of beach.
264	— 2·1	
300	— 5·8	
400	— 8·8	
500	— 9·8	
600	—15·8	
700	—20·3	
800	—12·8	
900	—18·8	
1 000	—28·8	
1 100	—40·8	

CROSS-SECTION No. 188.

No. 245 of 1889.

[Origin: Latitude, 42° 04′ 40″·4; longitude, 70° 13′ 10″·5; azimuth, 157° 00′.]

Distance from origin.	Height above or below mean sea level.	Remarks.
Metres.	*Feet.*	
0	16·5	
20	10·6	
40	7·8	
60	3·8	
80	7·2	
100	33·1	
120	37·9	
140	33·7	
160	24·6	
180	17·4	
200	12·8	
220	7·9	Beach stake.
232	8·8	Crest of beach.
240	5·1	
248	— 3·3	
300	— 9·3	
350	—12·3	
400	— 7·8	
500	— 8·8	
600	—15·3	
700	—19·8	
800	—17·3	
900	—21·3	
1 000	—48·8	

Cross-sections of the shore of Cape Cod, etc.—Continued.

CROSS-SECTION No. 189.

No. 247 of 1889.

[Origin: Latitude, 42° 04′ 36″·0; longitude, 70° 13′ 22″·0; azimuth, 156° 30′.]

Distance from origin.	Height above or below mean sea level.	Remarks.
Metres.	*Feet.*	
0	5·6	
20	6·0	
40	6·1	
60	6·7	
80	7·1	
100	11·9	
120	23·1	
140	32·0	
160	33·3	
180	27·5	
200	26·8	
214	24·1	Bluff stake.
220	17·4	
240	8·6	Beach stake.
251	8·4	Crest of beach.
268	— 3·2	
300	— 4·8	
400	—11·8	
500	— 9·3	
600	—14·8	
700	—20·3	
800	—18·8	
900	—20·8	
1 000	—46·8	
1 070	—72·8	

CROSS-SECTION No. 190.

No. 249 of 1889.

[Origin: Latitude, 42° 04′ 32″·8; longitude, 70° 13′ 34″·2; azimuth, 154° 50′.]

Distance from origin.	Height above or below mean sea level.	Remarks.
Metres.	*Feet.*	
0	15·5	
20	5·2	
40	5·6	
60	18·8	
80	13·0	
100	27·1	
120	31·4	
140	23·5	
160	26·6	
180	24·3	
197	22·6	Bluff stake.
200	21·1	
220	9·2	Beach stake.
235	8·8	Crest of beach.
240	7·4	
260	— 1·5	
272	— 2·7	
300	— 7·8	
400	—12·8	
500	— 6·6	
600	—14·8	
700	—20·3	
800	—19·3	
850	—21·8	
900	—40·8	

Cross-sections of the shore of Cape Cod, etc.—Continued.

CROSS-SECTION No. 191.

No. 251 of 1889.

[Origin: Latitude, 42° 04′ 28″·9; longitude, 70° 13′ 46″·0; azimuth, 151° 45′.]

Distance from origin.	Height above or below mean sea level.	Remarks.
Metres.	*Feet.*	
0	24·7	
20	24·6	
40	29·9	
60	26·8	
80	14·4	
100	16·9	
120	24·6	
140	28·2	
160	25·2	
180	19·5	
200	9·8	Beach stake.
220	8·2	
225	7·9	Crest of beach.
247	— 3·4	
300	— 9·3	
400	—11·8	
500	—11·6	
600	—15·3	
700	—19·3	
800	—27·8	
900	—55·8	

CROSS-SECTION No. 192.

No. 253 of 1889.

[Origin: Latitude, 42° 04′ 23″·5; longitude, 70° 13′ 55″·8; azimuth, 147° 00′.]

Distance from origin.	Height above or below mean sea level.	Remarks.
Metres.	*Feet.*	
0	19·3	
20	11·9	On slope of ridge.
40	8·0	
60	7·5	
80	7·5	
100	7·3	
120	8·5	
140	13·1	
160	21·5	
180	25·2	
188	25·0	Bluff stake.
200	23·0	
220	15·7	
240	12·1	Beach stake.
260	7·8	
268	8·3	Crest of beach.
280	4·0	
295	— 1·9	
300	— 3·8	
400	—15·8	
500	— 9·3	
600	—13·8	
700	—21·3	
800	—52·8	
850	—70·8	

Cross-sections of the shore of Cape Cod, etc.—Continued.

CROSS-SECTION No. 193.

No. 255 of 1889.

[Origin: Latitude, 42° 04′ 19″·0; longitude, 70° 14′ 06″·2; azimuth, 136° 40′.]

Distance from origin.	Height above or below mean sea level.	Remarks.
Metres.	*Feet.*	
0	20·4	
20	18·8	
40	6·9	
60	9·1	
80	10·2	
100	14·4	
120	20·8	
140	22·7	
160	19·3	
180	13·3	
200	13·2	Beach stake.
220	8·9	
300	—10·6	
400	— 8·6	
500	—13·1	
600	—22·6	
700	—65·6	

CROSS-SECTION No. 194.

No. 257 of 1889.

[Origin: Latitude, 42° 44′ 12″·7; longitude, 70° 14′ 14″·2; azimuth, 128° 00′.]

Distance from origin.	Height above or below mean sea level.	Remarks.
Metres.	*Feet.*	
0	7·0	
20	13·8	
40	11·3	
60	14·5	
80	7·5	
100	8·3	
120	10·3	
140	11·8	
160	14·8	
180	17·7	
200	11·7	Beach stake.
220	7·7	
240	8·0	
300	—10·6	
400	—13·6	
500	—28·6	
600	—89·6	

Cross-sections of the shore of Cape Cod, etc.—Continued.

CROSS-SECTION No. 195.

No. 259 of 1889.

[Origin: Latitude, 42° 04′ 04″·7; longitude, 70° 14′ 20″·3; azimuth, 123° 10′.]

Distance from origin.	Height above or below mean sea level.	Remarks.
Metres.	*Feet.*	
0	19·0	
20	14·5	
40	9·1	
60	8·6	
80	8·6	
100	9·1	
120	13·1	
140	16·7	
160	7·8	
180	7·6	
200	15·2	
220	12·7	Beach stake.
240	10·0	
260	8·0	
300	— 7·6	
400	—12·6	
500	—29·6	
560	—82·6	

CROSS-SECTION No. 196.

No. 261 of 1889.

[Origin: Latitude, 42° 03′ 57″·5; longitude, 70° 14′ 28″·6; azimuth, 120° 45′.]

Distance from origin.	Height above or below mean sea level.	Remarks.
Metres.	*Feet.*	
0	5·4	
20	5·4	
40	5·4	
60	10·6	
80	17·6	
100	21·0	
120	13·6	
140	11·0	
160	24·8	
180	12·6	Beach stake.
200	9.4	
220	8·0	
300	— 9·6	
400	— 21·1	
500	o —100·0	o / " } No bottom at this depth.

Cross-sections of the shore of Cape Cod, etc.—Continued.

CROSS-SECTION No. 197.

No. 263 of 1889.

[Origin: Latitude, 42° 03′ 49″·5; longitude, 70° 14′ 32″·5; azimuth, 109° 30′.]

Distance from origin.	Height above or below mean sea level.	Remarks.
Metres.	*Feet.*	
0	8·9	
20	6·8	
40	7·8	
60	10·5	
80	12·0	
100	15·8	
120	21·2	
140	16·4	
160	21·4	
180	17·1	
200	9·3	Beach stake.
220	7·5	
240	7·8	
300	— 6·6	
400	—16·6	
500	—75·6	
525	—95·6	

CROSS-SECTION No. 198.

No. 265 of 1889.

[Origin: At dwelling of Race Point light keeper. Latitude, 42° 03′ 43″·2; longitude, 70° 14′ 39″·6; azimuth, 61° 40′.]

Distance from origin.	Height above or below mean sea level.	Remarks.
Metres.	*Feet.*	
0	12·2	
18	9·5	
38	8·5	
58	17·1	
78	16·9	
98	15·2	
118	8·4	
138	7·5	Beach stake.
158	5·4	
163	2·5	
200	— 4·6	
300	—10·1	
400	—25·6	
460	—90·6	

Cross-sections of the shore of Cape Cod, etc.—Continued.

CROSS-SECTION No. 199.

No. 267 of 1889.

[Origin: Latitude, 42° 03′ 42″·5; longitude, 70° 14′ 27″·8; azimuth, 24° 32′.]

Distance from origin.	Height above or below mean sea level.	Remarks.
Metres.	*Feet.*	
0	3·9	
20	5·1	
40	10·5	
60	13·0	
80	6·4	
100	7·4	
120	7·9	
140	11·0	
*B. M.	14·2	
160	10·9	
180	7·9	
200	7·9	Beach stake.
220	2·5	
300	— 7·6	
400	—10·1	
500	—13·6	
600	—18·6	
700	—64·6	
735	—77·6	

CROSS-SECTION No. 200.

No. 269 of 1889.

[Origin: Latitude, 42° 03′ 34″·1; longitude, 70° 14′ 18″·9; azimuth, 24° 40′.]

Distance from origin.	Height above or below mean sea level.	Remarks.
Metres.	*Feet.*	
0	2·5	
16	5·0	
36	5·2	
56	4·5	Beach stake.
66	1·9	
100	— 8·6	
200	—12·6	
300	—14·1	
400	—14·6	
500	—18·1	
600	—26·6	
700	—78·6	

*Southwest boundary stone of light-house reservation, Race Point, Cape Cod, Mass.

Cross-sections of the shore of Cape Cod, etc.—Continued.

CROSS-SECTION No. 201.

No. 271 of 1889.

[Origin: Latitude, 42° 03′ 34″·5; longitude, 70° 14′ 04″·3; azimuth, 24° 45′.]

Distance from origin.	Height above or below mean sea level.	Remarks.
Metres.	*Feet.*	
0	3·7	
20	4·3	Marsh Hatches Harbor.
40	13·4	
60	14·6	
80	7·5	
100	5·2	
120	10·3	
140	4·4	
160	6·8	
180	5·3	
190	10·0	
200	3·0	Beach stake.
221	0·7	
350	— 6·1	
400	— 11·1	
500	— 14·1	
600	— 16·4	
700	— 18·1	
800	— 21·1	
900	— 26·6	
1 000	— 38·6	
1 070	—102·6	

CROSS-SECTION No. 202.

No. 273 of 1889.

[Origin: Latitude, 42° 03′ 30″·5: longitude, 70° 13′ 52″·3; azimuth, 24° 45′.]

Distance from origin.	Height above or below mean sea level.	Remarks.
Metres.	*Feet.*	
0	10·3	
20	10·0	
40	10·8	
60	7·0	
80	5·2	
100	9·0	
120	14·8	
140	13·5	
160	8·0	
180	7·6	
190	7·4	
200	3·3	Beach stake.
208	3·1	
300	—10·1	
400	—13·1	
500	—14·1	
600	—15·6	
700	—16·1	
800	—19·6	
900	—22·1	
1 000	—25·6	
1 100	—28·6	
1 200	—33·6	
1 300	—41·6	

Cross-sections of the shore of Cape Cod, etc.—Continued.

CROSS-SECTION No. 203.

No. 275 of 1889.

[Origin: Latitude, 42° 03′ 23″·8; longitude, 70° 13′ 38″.5; azimuth, 47° 15′.]

Distance from origin.	Height above or below mean sea level.	Ramarks.
Metres.	*Feet.*	
0	8·4	
20	10·3	
40	8·1	
60	7·9	
80	9·9	
100	15·2	
120	24·8	
140	34·0	
160	29·8	
180	23·5	
200	9·4	Beach stake.
220	2·9	
225	— 1·5	
300	— 9·6	
400	—11·6	
500	—13·8	
600	—15·1	
700	—18·6	
800	—19·6	
900	—21·6	
1 000	—24·6	
1 100	—27·6	
1 200	—34·6	
1 300	—66·6	

CROSS-SECTION No. 204.

No. 277 of 1889.

[Origin: Latitude, 42° 03′ 16″·0; longitude, 70° 13′ 29″·7; azimuth, 53° 55′.]

Distance from origin.	Height above or below mean sea level.	Remarks.
Metres.	*Feet.*	
0	23·9	
20	34·5	
40	39·1	
60	17·4	
80	11·0	
100	15·6	
120	8·8	
140	2·6	
160	2·8	
180	7·1	
200	13·0	
220	12·0	Beach stake.
248	0·4	
300	—10·1	
400	—11·6	
500	—14·1	
600	—16·1	
700	—18·6	
800	—20·1	
900	—24·1	
1 000	—25·6	
1 100	—27·1	
1 200	—32·6	
1 300	—44·6	

Cross-sections of the shore of Cape Cod, etc.—Continued.

CROSS-SECTION No. 205.

No. 279 of 1889.

[Origin: Latitude, 42° 03′ 08″·1; longitude, 70° 13′ 22″·6; azimuth, 52° 45′.]

Distance from origin.	Height above or below mean sea level.	Remarks.
Metres.	*Feet.*	
0	15·5	
20	9·7	
40	10·4	
60	12·9	
80	16·1	
100	14·3	
120	10·2	
140	3·4	
160	4·2	
180	4·9	
200	8·4	Beach stake.
206	12·6	
232	1·2	
300	— 9·6	
400	—14·6	
500	—17·6	
600	—17·8	
700	—18·1	
800	—19·6	
900	—20·1	
1 000	—22·1	
1 100	—24·1	
1 200	—23·1	
1 300	—30·3	
1 360	—75·6	

CROSS-SECTION No. 206.

No. 281 of 1889.

[Origin: Latitude, 42° 03′ 00″·2; longitude, 70° 13′ 14″·8; azimuth, 52° 45′.]

Distance from origin.	Height above or below mean sea level.	Remarks.
Metres.	*Feet.*	
0	12·2	
20	10·5	
40	8·3	
60	10·3	
80	13·9	
100	4·4	
120	4·6	
140	5·0	
160	5·4	
180	11·5	
190	12·4	
200	6·2	Beach stake.
220	2·4	
300	— 4·6	
400	—11·1	
500	—14·1	
600	—16·6	
700	—18·6	
800	—19·1	
900	—19·6	
1 000	—21·1	
1 100	—22·1	
1 200	—21·1	
1 300	—19·6	
1 400	—24·6	
1 485	—76·6	

Cross-sections of the shore of Cape Cod, etc.—Continued.

CROSS-SECTION No. 207.

No. 283 of 1889.

[Origin: Latitude, 42° 02′ 51″·2; longitude, 70° 13′ 08″·0; azimuth, 57° 00′.]

Distance from origin.	Height above or below mean sea level.	Remarks.
Metres.	*Feet.*	
0	13·4	
20	12·4	
40	7·2	
60	3·7	
80	3·5	
100	3·5	
120	3·8	
140	6·6	
154	8·6	
160	7·6	Beach stake.
180	2·7	
205	— 4·0	
250	— 9·6	
300	— 11·6	
400	— 16·1	
500	— 17·6	
600	— 20·1	
700	— 20·1	
800	— 20·4	
900	— 21·1	
1 000	— 20·1	
1 100	— 18·1	
1 200	— 19·1	
1 300	— 39·6	
1 340	—100·	No bottom at this depth.

CROSS-SECTION No. 208.

No. 285 of 1889.

[Origin: Latitude, 42° 02′ 42″·5; longitude, 70° 13′ 00″·7; azimuth, 62° 30′.]

Distance from origin.	Height above or below mean sea level.	Remarks.
Metres.	*Feet.*	
0	13·4	
20	8·6	
40	3·9	
60	3·9	
80	4·0	
100	3·8	
120	3·7	
140	5·7	
160	8·4	Beach stake.
180	2·5	
207	— 3·3	
300	— 11·6	
400	— 15·1	
500	— 16·1	
600	— 17·8	
700	— 19·1	
800	— 20.1	
900	— 19·6	
1 000	— 18·6	
1 100	— 17·6	
1 200	— 18·6	
1 300	— 59·6	
1 340	—100·	No bottom at this depth.

Cross-sections of the shore of Cape Cod, etc.—Continued.

CROSS-SECTION No. 209.

No. 287 of 1889.

[Origin: Latitude, 42° 02′ 33″·4; longitude, 70° 12′ 53″·9; azimuth, 68° 25′.]

Distance from origin.	Height above or below mean sea level.	Remarks.
Metres.	*Feet.*	
0	15·3	
20	12·2	
40	5·2	
60	3·9	
80	4·1	
100	4·3	
120	4·8	
140	5·7	
160	6·8	
168	7·7	
180	5·8	Beach stake.
200	1·8	

CROSS-SECTION No. 209—Continued.

No. 287 of 1889.

Distance from origin.	Height above or below mean sea level.	Remarks.
Metres.	*Feet.*	
224	— 2·8	
300	—12·1	
400	—13·6	
500	—17·6	
600	—15·1	
700	—19·6	
800	—19·6	
900	—18·1	
1 000	—17·6	
1 100	—17·6	
1 200	—22·6	
1 280	—78·6	

Cross-sections of the shore of Cape Cod, etc.—Continued.

CROSS-SECTION No. 210. No. 289 of 1889. [Origin: Latitude, 42° 02′ 23″·7; longitude, 70° 12′ 50″·6; azimuth, 70° 50′.]			CROSS-SECTION No. 211. No. 291 of 1889. [Origin: Latitude, 42° 02′ 14″·3; longitude, 70° 12′ 47″·8; azimuth, 68° 25′.]		
Distance from origin.	Height above or below mean sea level.	Remarks.	Distance from origin.	Height above or below mean sea level.	Remarks.
Metres.	*Feet.*		*Metres.*	*Feet.*	
0	12·6		0	4·4	
20	3·5	Edge of marsh.	20	4·9	
40	3·8		40	5·1	
60	2·6		60	5·1	
80	3·4		80	9·2	
100	4·4	Edge of marsh.	100	16·7	
120	10·6		117	15·0	Grass line.
140	22·3		120	10·2	Beach stake.
148	20·6		140	3·2	
160	6·4	Beach stake.	166	— 1·1	
180	1·3		200	— 7·1	
198	— 2·0		300	— 12·6	
300	— 12·4		400	— 14·6	
400	— 12·6		500	— 15·6	
500	— 17·6		600	— 15·6	
600	— 19·1		700	— 17·6	
700	— 18·6		800	— 18·6	
800	— 16·6		870	— 66·6	
900	— 16·6		930	—100·	No bottom at this depth.
1 000	— 17·6				
1 100	— 56·6				
1 160	—100·	No bottom at this depth.			

Cross-sections of the shore of Cape Cod, etc.—Continued.

CROSS-SECTION No. 212.

No. 293 of 1889.

[Origin: Latitude, 42° 02′ 06″·3; longitude, 70° 12′ 43″·1; azimuth, 53° 55′.]

Distance from origin.	Height above or below mean sea level.	Remarks.
Metres.	*Feet.*	
0	3·6	
20	4·2	
40	5·1	
60	10·9	
80	15·1	
100	13·4	Grass line.
120	7·7	Beach stake.
140	3·5	
162	— 0·6	
200	— 9·6	
300	—12·6	
400	—14·6	
500	—16·6	
600	—17·1	
700	—27·6	
750	—95·6	

CROSS-SECTION No. 213.

No. 295 of 1889.

[Origin: Latitude, 42° 01′ 58″·9; longitude, 70° 12′ 35″·6; azimuth, 48° 30′.]

Distance from origin.	Height above or below mean sea level.	Remarks.
Metres.	*Feet.*	
0	3·4	
20	4·1	
40	6·4	
60	15·9	
76	13·5	Grass line.
80	8·4	Beach stake.
100	2·3	
122	± 0·0	
200	— 13·1	
300	— 14·6	
400	— 14·1	
500	— 15·1	
600	— 19·1	
700	—100·	No bottom at this depth.

Cross-sections of the shore of Cape Cod, etc.—Continued.

CROSS-SECTION No. 214.

No. 297 of 1889.

[Origin: Latitude, 42° 01′ 52″·8; longitude, 70° 12′ 25″·6; azimuth, 45° 30′.]

Distance from origin.	Height above or below mean sea level.	Remarks.
Metres.	*Feet.*	
0	2·0	
20	1·9	
40	2·3	
60	4·3	
80	7·3	
100	13·8	Grass line.
114	6·3	
120	8·3	Beach stake.
140	1·5	
160	0·6	
200	— 8·1	
300	—12·6	
400	—16·1	
500	—18·1	
600	—19·6	
700	—23·1	
760	—26·6	

CROSS-SECTION No. 215.

No. 299 of 1889.

[Origin: Latitude, 42° 01′ 43″·6; longitude, 70° 12′ 19″·4; azimuth, 42° 51′.]

0	--	
100	— 9·6	
200	— 14·6	
300	— 17·1	
400	— 19·6	
500	— 21·1	
600	— 18·6	
650	— 32·6	
700	—100·	No bottom at this depth.

CROSS-SECTION No. 216.

No. 301 of 1889.

[Origin: Latitude, 42° 01′ 36″·9; longitude, 70° 12′ 10″·1; azimuth, 40° 30′.]

Distance from origin.	Height above or below mean sea level.	Remarks.
Metres.	*Feet.*	
0	--	
100	— 7·1	
200	—13·6	
300	—14·6	
400	—15·6	
500	—15·6	
600	—15·4	
700	—18·6	
770	—37·6	

CROSS-SECTION No. 217.

No. 303 of 1889.

[Origin: Latitude, 42° 01′ 30″·5; longitude, 70° 12′ 00″·4; azimuth, 45° 35′.]

0	--	
100	0·9	
200	— 13·1	
300	— 14·6	
400	— 14·1	
500	— 12·6	
600	— 57·6	
670	—100·	No bottom at this depth.

Cross-sections of the shore of Cape Cod, etc.—Continued.

CROSS-SECTION No. 218.

No. 305 of 1889.

[Origin: Latitude, 42° 01′ 23″·3; longitude, 70° 11′ 51″·6; azimuth, 45° 10′.]

Distance from origin.	Height above or below mean sea level.	Remarks.
Metres.	*Feet.*	
0	--	
100	— 4·6	
200	— 12·6	
300	— 20·6	
350	—100·	No bottom at this depth.

CROSS-SECTION No. 219.

No. 307 of 1889.

[Origin: Latitude, 42° 01′ 17″·0; longitude, 70° 11′ 41″·5; azimuth, 33° 15′.]

Distance from origin.	Height above or below mean sea level.	Remarks.
0	--	
100	— 6·6	
150	—16·6	
220	—86·6	

CROSS-SECTION No. 220.

No. 309 of 1889.

[Origin: Latitude, 42° 01′ 13″·8; longitude, 70° 11′ 29″·5; azimuth, 16° 50′.]

Distance from origin.	Height above or below mean sea level.	Remarks.
0	--	
100	— 1·6	
200	—58·6	

CROSS-SECTION No. 221.

No. 311 of 1889.

[Origin: Latitude, 42° 01′ 12″·2; longitude, 70° 11′ 16″·8; azimuth, 00° 00′.]

Distance from origin.	Height above or below mean sea level.	Remarks.
Metres.	*Feet.*	
0	..	
100	— 7·6	
150	—30·6	
190	—88·6	

CROSS-SECTION No. 222.

No. 313 of 1889.

[Origin: Latitude, 42° 01′ 14″·2; longitude, 70° 11′ 03″·9; azimuth, 343° 15′.]

Distance from origin.	Height above or below mean sea level.	Remarks.
0	--	
100	— 8·6	
190	—94·6	

CROSS-SECTION No. 223.

No. 315 of 1889.

[Origin: Latitude, 42° 01′ 17″·7; longitude, 70° 10′ 52″·0; azimuth, 326° 58′.]

Distance from origin.	Height above or below mean sea level.	Remarks.
0	--	
100	— 10·6	
150	— 47·6	
180	—100·	No bottom at this depth.

Cross sections of the shore of Cape Cod, etc.—Continued.

CROSS-SECTION No. 224.

No. 317 of 1889.

[Origin: Latitude, 42° 01′ 24″·2; longitude, 70° 10′ 42″·3; azimuth, 314° 00′.]

Distance from origin.	Height above or below mean sea level.	Remarks.
Metres.	*Feet.*	
0	----	
140	—10·6	
175	—71·6	

CROSS-SECTION No. 225.

No. 319 of 1889.

[Origin: Latitude, 42° 01′ 31″·2; longitude, 70° 10′ 33″·2; azimuth, 312° 25′.]

0	----	
130	— 6·6	
190	—49·6	

CROSS-SECTION No. 226.

No. 321 of 1889.

[Origin: Latitude, 42° 01′ 37″·3; longitude, 70° 10′ 22″·1; azimuth, 304° 50′.]

0	----	
50	— 7·6	
100	—24·6	
120	—49·6	

CROSS SECTION No. 227.

No. 323 of 1889.

[Origin: Latitude, 42° 01′ 47″·0; longitude, 70° 10′ 17″·9; azimuth, 299° 25′.]

Distance from origin.	Height above or below mean sea level.	Remarks.
Metres.	*Feet.*	
0	----	
140	— 4·6	
200	—16·1	
260	—33·6	

CROSS-SECTION No. 228.

No. 325 of 1889.

[Origin: Latitude, 42° 01′ 56″·1; longitude, 70° 10′ 13″·0; azimuth, 298° 25′.]

0	----	
100	—10·1	
200	—13·6	
300	—16·6	
400	—23·6	
460	—70·6	

CROSS-SECTION No. 229.

No. 326 of 1889.

[Origin: Latitude, 42° 02′ 00″·0; longitude, 70° 10′ 08″·6; azimuth, 299° 25′.]

0	----	
100	— 8·4	
200	— 13·1	
300	— 16·1	
400	— 21·1	
450	— 45·6	
500	—100·0	No bottom at this depth

Cross-sections in Cape Cod Bay.

CROSS-SECTION No. 0.

1889.

[Origin: Latitude, 42° 02′ 38″·1; longitude, 70° 06′ 22″·4; azimuth, 40° 50′.]

Distance from origin.	Height above or below mean sea level.	Remarks.
Metres.	*Feet.*	
0	34·4	
18	29·6	
38	38·2	
58	45·6	
78	48·8	
98	55·4	
118	44·0	
138	19·3	Beach stake.
158	4·6	
174	— 1·8	
200	— 4·6	
300	— 5·8	
400	— 7·8	
500	— 8·1	
600	—11·6	
700	—17·6	
800	—22·6	
900	—28·1	
1 000	—33·6	
1 100	—38·1	
1 200	—41·6	
1 250	—43·6	

CROSS SECTION No. 2.

1889.

[Origin: Latitude, 42° 02′ 44″·3; longitude, 70° 06′ 32″·6; azimuth, 40° 50′.]

Distance from origin.	Height above or below mean sea level.	Remarks.
Metres.	*Feet.*	
0	49·9	
20	23·2	
40	11·8	
60	7·2	
80	6·9	
100	9·1	
114	17·0	
120	11·0	
140	3·1	
153	— 2·1	
200	— 4·6	
300	— 6·6	
400	— 8·1	
500	— 9·1	
600	—10·6	
700	—16·8	
800	—22·1	
900	—25·6	
1 000	—30·6	
1 100	—34·6	
1 200	—37·6	
1 300	—43·1	
1 400	—44·6	

Cross-sections in Cape Cod Bay—Continued.

CROSS-SECTION No. 3.

1889.

[Origin: Latitude, 42° 02′ 49″·9; longitude, 70° 06′ 34″·9; azimuth, 39° 50′.]

Distance from origin.	Height above or below mean sea level.	Remarks.
Metres.	*Feet.*	
0	35·9	
20	39·0	
40	39·8	
60	41·3	
80	27·2	
100	14·2	
120	19·2	
138	15·9	Center of railroad track.
160	5·8	
180	6·7	
200	6·8	
218	15·2	
220	13·1	
224	11·4	
240	9·0	
254	— 2·5	
300	— 5·6	
400	— 6·6	
500	— 7·4	
600	— 9·1	
700	—10·6	
800	—18·6	
900	—22·6	
1 000	—27·6	
1 100	—29·6	
1 200	—32·6	
1 300	—35·6	
1 400	—39·6	
1 500	—43·6	
1 600	—47·6	

CROSS-SECTION No. 4.

1889.

[Origin: Latitude, 42° 02′ 47″·5; longitude, 70° 06′ 46″·2; azimuth, 38° 30′.]

Distance from origin.	Height above or below mean sea level.	Remarks.
Metres.	*Feet.*	
0	28·6	
20	29·9	
40	29·8	
60	26·5	
80	21·9	
100	14·6	
120	11·8	
140	5·8	
160	5·0	
180	4·6	
188	9·8	Center of railroad track.
200	4·7	
220	4·5	
240	6·7	
253	14·5	
260	11·0	
280	3·3	
295	— 2·9	
400	— 6·6	
500	— 7·4	
600	— 7·4	
700	— 8·8	
800	—14·1	
900	—21·6	
1 000	—26·1	
1 100	—30·6	
1 200	—31·6	
1 300	—34·1	
1 400	—36·6	
1 460	—39·6	

Cross-sections in Cape Cod Bay—Continued.

CROSS-SECTION No. 5. 1889. [Origin: Latitude, 42° 02′ 53″·5; longitude, 70° 06′ 47″·8; azimuth, 38° 40.]		
Distance from origin.	Height above or below mean sea level.	Remarks.
Metres.	*Feet.*	
0	3·9	
20	4·1	
40	4·4	
60	6·5	Center of railroad track.
80	4·6	
100	5·1	
120	13·9	
124	12·4	
140	4·1	
157	— 3·1	
200	— 6·1	
300	— 6·8	
400	— 6·8	
500	— 7·8	
600	— 9·1	
700	—14·6	
800	—22·6	
900	—28·6	
1 000	—30·6	
1 100	—32·6	
1 200	—34·1	
1 300	—36·6	

CROSS-SECTION No. 7. 1889. [Origin: Latitude, 42° 03′ 00″·6; longitude, 70° 06′ 57″·7; azimuth, 32° 05′.]		
Distance from origin.	Height above or below mean sea level.	Remarks.
Metres.	*Feet.*	
0	2·9	
20	3·3	
40	4·8	
60	4·6	
80	4·7	
101	6·4	Center of railroad track.
120	2·8	
140	7·2	
157	15·9	
160	14·8	
166	11·9	
180	4·4	
199	— 3·3	
300	— 7·1	
400	— 6·6	
500	— 7·8	
600	— 8·6	
700	—12·6	
800	—15·1	
900	—21·6	
1 000	—29·6	
1 100	—32·6	
1 200	—32·6	
1 300	—32·6	
1 400	—37·6	
1 500	-40·6	
1 600	—45·6	

Cross-sections in Cape Cod Bay—Continued.

CROSS SECTION No. 9.

1889.

[Origin: Latitude, 42° 03′ 05″·7; longitude, 70° 07′ 09″·1; azimuth, 31° 35′.]

Distance from origin.	Height above or below mean sea level.	Remarks.
Metres.	*Feet.*	
0	3·7	
20	3·4	
40	3·4	
60	3·5	
80	1·2	
88	6·6	Center of railroad track.
100	5·0	
120	1·8	
140	9·2	
160	13·8	Beach stake.
165	10·4	
180	4·0	
198	— 3·8	
300	— 5·9	
400	— 6·9	
500	— 7·9	
600	— 8·9	
700	—10·7	
800	—13·2	
900	—15·7	
1 000	—22·7	
1 100	—30·7	
1 200	—31·7	
1 300	—33·7	
1 400	—35·2	
1 500	—37·2	

CROSS-SECTION No. 11.

1889.

[Origin: Latitude, 42° 03′ 11″·3; longitude, 70° 07′ 19″·6; azimuth, 31° 40′.]

Distance from origin.	Height above or below mean sea level.	Remarks.
Metres.	*Feet.*	
0	2·6	
20	4·3	
40	2·9	
60	1·5	
80	4·1	
100	2·9	
115	6·4	Center of railroad track.
120	6·2	
140	5·7	
160	11·4	
180	13·6	
190	12·0	Crest of beach.
200	6·2	
225	— 4·1	
300	— 6·7	
400	— 5·7	
500	— 6·2	
600	— 8·7	
700	—10·7	
800	—12·5	
900	—12·7	
1 000	—15·7	
1 100	—21·2	
1 200	—25·7	
1 300	—28·7	
1 400	—30·7	
1 500	—32·7	
1 600	—36·7	

Cross-sections in Cape Cod Bay—Continued.

CROSS-SECTION No. 13.

1889.

[Origin: Latitude, 42° 03′ 13″·7; longitude, 70° 07′ 33″·0; azimuth, 27° 45′.]

Distance from origin.	Height above or below mean sea level.	Remarks.
Metres.	*Feet.*	
0	0·8	
14	3·8	
34	11·9	
45½	6·4	Center of railroad track.
54	10·8	
74	22·3	
94	14·2	
104	12·8	
114	6·9	
141	— 4·2	
200	— 6·2	
300	— 6·7	
400	— 7·2	
500	— 7·2	
600	— 9·2	
700	—10·7	
800	—13·2	
900	—12·2	
1 000	—18·2	
1 100	—23·2	
1 200	—26·2	
1 300	—29.2	
1 400	—30·7	
1 500	—32·7	
1 550	—35·7	

CROSS-SECTION No. 15.

1889.

[Origin: Latitude, 42° 03′ 17″·2; longitude, 70° 07′ 45″·1; azimuth, 27° 50′.]

Distance from origin.	Height above or below mean sea level.	Remarks.
Metres.	*Feet.*	
0	1·4	
16½	6·3	Center of railroad track.
38	12·6	
58	13·1	
78	9·4	
98	1·1	
112	— 5·3	
200	— 6·2	
300	— 7·2	
400	— 7·2	
500	— 8·2	
600	— 8·2	
700	—10·2	
800	—11·2	
900	—12·2	
1 000	—17·2	
1 100	—22·7	
1 200	—25·7	
1 300	—28·2	
1 400	—29·7	
1 500	—31·7	
1 600	—35·7	
1 700	—37·7	

Cross-sections in Cape Cod Bay—Continued.

CROSS-SECTION No. 17. 1889. [Origin: Latitude, 42° 03′ 21″·2; longitude, 70° 07′ 57″·3; azimuth, 26° 25′.]			CROSS-SECTION No. 19. 1889. [Origin: Latitude, 42° 03′ 26″·4; longitude, 70° 08′ 08″·3; azimuth, 28° 00′.]		
Distance from origin.	Height above or below mean sea level.	Remarks.	Distance from origin.	Height above or below mean sea level.	Remarks.
Metres.	*Feet.*		*Metres.*	*Feet.*	
0	7·9		0	1·8	
15	7·7		20	7·2	
35	9·8		27	7·7	Center of railroad track.
55	11·1		40	10·0	
75	12·8		60	8·0	
95	10·0		79	8·8	
115	— 0·2		100	— 1·2	
135	— 3·6		120	— 3·1	
155	— 4·5		140	— 3·1	
175	— 4·8		160	— 3·5	
195	— 4·6		180	— 3·6	
300	— 4·7		200	— 3·6	
400	— 7·2		220	— 3·8	
500	— 8·2		300	— 5·2	
600	— 7·2		400	— 5·2	
700	— 9·2		500	— 6·2	
800	— 9·2		600	— 7·7	
900	—11·2		700	— 9·2	
1 000	—16·7		800	— 8·9	
1 100	—21·7		900	— 9·9	
1 200	—24·7		1 000	—11·7	
1 300	—26·7		1 100	—16·7	
1 400	—29·7		1 200	—22·7	
1 500	—31·7		1 300	—24·7	
1 600	—34·7		1 400	—25·7	
1 700	—36·7		1 500	—26·7	
1 800	—42·7		1 600	—29·7	
			1 700	—33·7	
			1 800	—36·7	
			1 900	—41·7	

Cross-sections in Cape Cod Bay—Continued.

CROSS-SECTION No. 21.

1889.

[Origin: Latitude, 42° 03′ 31″·6; longitude, 70° 08′ 18″·5; azimuth, 40° 10′.]

Distance from origin.	Height above or below mean sea level.	Remarks.
Metres.	*Feet.*	
0	1·5	
22	6·1	Center of railroad track.
40	8·4	
60	9·5	
80	8·2	
94	7·3	
100	5·2	
108	— 4·0	
200	— 4·5	
300	— 4·5	
400	— 4·7	
500	— 5·5	
600	— 5·2	
700	— 5·5	
800	— 6·5	
900	— 7·9	
1 000	— 8·5	
1 100	—10·7	
1 200	—11·7	
1 300	—17·2	
1 400	—24·2	
1 500	—24·7	
1 600	—25·7	
1 700	—27·7	
1 800	—29·7	
1 900	—33·7	

CROSS-SECTION No. 23.

1889.

[Origin: Latitude, 42° 03′ 37″·9; longitude, 70° 08′ 28″·5; azimuth, 40° 10′.]

Distance from origin.	Height above or below mean sea level.	Remarks.
Metres.	*Feet.*	
0	2·3	
20	3·9	
38	6·2	Center of railroad track.
60	10·0	
80	8·0	
94	— 3·3	
200	— 3·5	
300	— 3·5	
400	— 3·7	
500	— 3·7	
600	— 4·2	
700	— 4·2	
800	— 6·2	
900	— 6·2	
1 000	— 5·9	
1 100	— 8·9	
1 200	— 7·9	
1 300	—11·2	
1 400	—14·7	
1 500	—21·7	
1 600	—22·7	
1 700	—24·7	
1 800	—25·7	
1 900	—27·7	
2 000	—31·7	
2 100	—35·7	

Cross-sections in Cape Cod Bay—Continued.

CROSS-SECTION No. 25.

1889.

[Origin: Latitude, 42° 03′ 43″·8; longitude, 70° 08′ 38″·5; azimuth, 37° 20′.]

Distance from origin.	Height above or below mean sea level.	Remarks.	Distance from origin.	Height above or below mean sea level.	Remarks.
Metres.	*Feet.*		*Metres.*	*Feet.*	
0	1·6		1 000	— 5·2	
10	1·9		1 100	— 8·7	
29½	8·9	Center of railroad track.	1 200	— 7·5	
			1 300	—12·7	
50	10·4		1 400	—12·7	
70	— 0·4		1 500	—21·2	
99	— 2·6		1 600	—21·7	
200	— 3·7		1 700	—23·2	
300	— 4·5		1 800	—24·2	
400	— 3·5		1 900	—24·7	
500	— 3·9		2 000	—26·7	
600	— 3·9		2 100	—29·2	
700	— 4·5		2 200	—33·7	
800	— 4·5		2 300	—39·7	
900	— 4·9		2 400	—53·7	

(Right half headed: CROSS-SECTION No. 25—Continued.)

Elevation of Bench-marks on Cape Cod.

[Determined by geodetic leveling, 1889.]

Number and locality of bench-mark.	Elevation above mean sea level.	
	Metres.	*Feet.*
B. M. XIII, on Cape Cod Light-House.	42·1653	138·337
B. M. XIV, near Cape Cod Light-House.	37·5770	123·284
T. B. M. 64, near Cape Cod Light-House.	39·2025	128·617
T. B. M. 69, High Head, Truro.	20·1455	66·094
B. M. XV, High Head, Truro.	1·8503	6·070
B. M. XVI, near railroad, between High Head and Provincetown.	3·3831	11·099
B. M. XVII, near railroad, between High Head and Provincetown.	4·2811	14·046
B. M. XVIII, on boundary between Truro and Provincetown.	2·6797	8·792
T. B. M. 76, in village of Provincetown.	7·1957	23·608
Cent. Ch. B. M., in village of Provincetown.	7·5621	24·810

NOTE.—T. B. M. 76 and Cent. Ch. B. M. connected with B. M. XVIII by duplicate line of common levels, in 1890.

DESCRIPTION OF BENCH-MARKS, CAPE COD, MASSACHUSETTS.

B. M. XIII.—On Cape Cod Light-house tower. The reference is the middle of a horizontal mark cut in one of the granite window-sills of the tower, Highlands of Truro, Cape Cod.

Established July 19, 1889.

B. M. XIV.—In a pasture owned by I. M. Small, about 360 metres back from Cape Cod Light-house. The reference is the top of a copper bolt leaded in a large rock. This rock is one of three in the immediate vicinity and has the letters "B. M." cut in top.

Established July 19, 1889.

T. B. M. 64.—The geometrical centre of the top of the stone post marking the northwest corner of the Cape Cod Light-house grounds. This post is of granite, having a dressed top with the letters "U. S. L. H. E." cut in it. It is also just at the corner of the platform in front of the Highland signal station.

Established July 2, 1889.

T. B. M. 69.—T. B. M. 69 is near High Head, town of Truro, Cape Cod, Mass., and is on land owned by Thomas F. Small. It is the centre of the top of a granite post that is located on top of the second bluff to the eastward of William Holden's house; the post has a dressed top, is about 6 by 6 inches, and projects one foot above ground; has the letters "U. S. No. 3" cut in one of its sides. Placed here by United States Engineers.

Established as a T. B. M., July 8, 1889.

B. M. XV.—B. M. XV is at High Head, town of Truro, Cape Cod, Mass., on the land of William Holden. It is the top of a copper bolt that is leaded in a large bowlder; the bowlder is buried about one foot under ground and is between wagon-track and fence, just east of William Holden's wagonhouse, being 34.8 metres from the northeast corner; it is 79.9 metres from northeast corner of house (upright part), and 57.9 metres from northwest corner of barn.

Established July 3, 1889.

Mr. William Holden knows its location.

B. M. XVI.—B. M. XVI is in the town of Truro, Cape Cod, Mass. It is the highest point on the top of the one hundred and sixteenth milepost, Cape Cod division of the Old Colony Railroad. The said post stands close to the track on the north side, and is about halfway between the villages or depots of North Truro and Provincetown; it is a rough granite post about one foot square, projecting five feet above ground; two adjoining faces near the top are dressed, on each of which are the figures "116" put on with black paint.

Established July 11, 1889.

B. M. XVII.—B. M. XVII is in the town of Truro, Cape Cod, Mass. It is the highest point on the top of the one hundred and seventeenth milepost, Cape Cod division of the Old Colony Railroad. The said post stands close to the track on the north side, and is about two and a half miles from the depot at Provincetown; it is also just east of where the wagon road crosses the track, near the east end of the dike, at Beach Point; it is a rough granite post about one foot square, projecting nearly six feet above ground; two adjoining faces near the top are dressed, on each of which are the figures "117" put on with black paint.

Established July 11, 1889.

B. M. XVIII.—B. M. XVIII is on the town line between the towns of Truro and Provincetown, Cape Cod, Mass. It is the highest point on the top of the rough granite post known as Truro Corner 5, and stands on the northeast side of the dike at Beach Point; it projects about eighteen inches above ground, and has the letter "T" cut in the Truro side and "P" in the Provincetown side of the post.

Standing just across the roadway (on the southwest side of dike) is a stone post similar in size and shape, that is also on the town line.

Established July 11, 1889.

T. B. M. 76.—T. B. M. 76 is in the village of Provincetown, Cape Cod, Mass. It is the top of the dressed granite post standing at the southeast corner of church-yard of Centenary M. E. Church; it is the post in which the iron post of the fence sets, corner of Commercial and Winthrop streets.

Standing just on the east side of the bench (in Winthrop street) is a rough granite post that is about one foot higher.

Established September 17, 1889.

Centenary Church B. M.—A line cut in brick foundation of Centenary M. E. Church, at Provincetown, Mass. B. M. is on east side of front part of church, 1½ metres east of front steps; it is on the fourth brick from southeast corner and on the second course below the wooden part of the building, marked $\frac{\text{U. S.}}{\text{1890.}}$

The B. M. is 27 metres northeast of T. B. M. 76.

Established June 30, 1890.

APPENDIX NO. 10–1891.

ON OBSERVATIONS OF CURRENTS WITH THE DIRECTION-CURRENT METER IN THE STRAITS OF FLORIDA AND IN THE GULF OF MEXICO, 1891.

A report by E. E. Haskell, Assistant.
Submitted for publication April 9, 1892.

The following report on the current observations made with the direction-current meter on board the Coast and Geodetic Survey steamer *Blake*, Lieut. C. E. Vreeland, U. S. Navy, commanding, in the Straits of Florida and the Gulf of Mexico, during the months of January, February, March, and April, 1891, is herewith respectfully submitted for publication.

The direction-current meter being a recent invention, a joint one by Mr. E. S. Ritchie, of compass fame, and the writer, a brief description of it may not be out of place at this point.

DESCRIPTION OF METER.

As its name implies, it is an instrument for determining the *direction* and the *velocity* or the *set* and the *drift* of a current of running water. It records these electrically on registers before the observer, so that when once in the water it only needs to be shifted from depth to depth at which information is required.

Illustration No. 13 gives a general view of the meter as it appears ready for lowering in the water, together with its direction and its velocity register. In observing a current it is suspended in the water from a boat at anchor by a single cable, the core of which is made up of the necessary number of insulated wires forming the operating circuits. The armor or covering of the cable furnishes the necessary tensile strength for carrying the weight of the meter and the strain brought by the friction of the running water on both meter and cable.

The velocity wheel is of the propeller or screw type, conical in front to constitute a self-clearing prow for all débris moving with the current.

The mass has been concentrated as closely as possible to its axis of revolution, thus making its moment of inertia a minimum. The bearings about which the wheel revolves are of large surface and entirely under cover. It is impossible for grit or sand to work into them. The electric connection or the "make" and "break" of the circuit for transmitting the number of revolutions of the wheel to the counting register in the boat is placed entirely inside the meter, where it is free from accident and sure of contact.

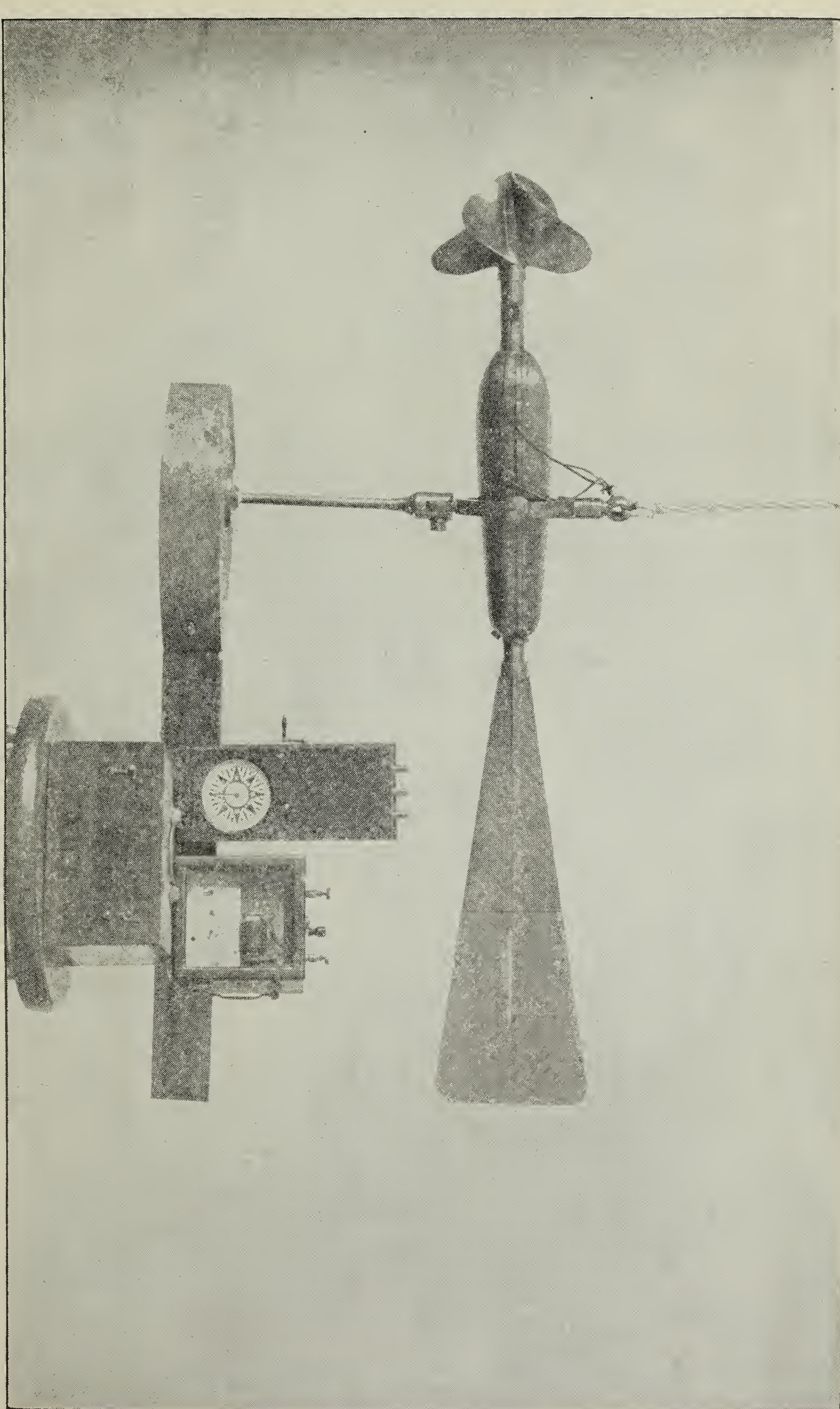
The central chamber or body of the meter is a compass, whose needle is free to assume the magnetic meridian at all times. This chamber is filled with oil, giving stability to and preventing rust of the needle and other mechanism. An expansion bag compensates for changes in temperature and establishes equilibrium of pressure between the inside and outside of the chamber when immersed. By the use of an electric circuit, the angle to the nearest degree between the direction of the current and the magnetic needle or meridian is transmitted to the *repeater* or direction register in the boat. The two observations or the *velocity* and the *direction* of the current can thus be taken simultaneously and repeated at will.

The main principles kept in view in the design and construction of the apparatus are: (1) That it should offer a minimum of interruption to the free flow of water; (2) that nothing should be allowed in proximity to the wheel that would tend to create an eddy or whirl; (3) that it should be extremely sensitive in conforming to the direction of the current, both horizontally and vertically; (4) that the current pressure should be integral and not differential in its action on the meter wheel (the pressure surface in this wheel is 44 square inches); (5) that the bearings of the wheel should be of large surface and so protected that they may be subject to a minimum of change in form by wear, thus maintaining a constant *rate;* (6) that it should not be frail but capable of withstanding rough treatment, to which through force of circumstances it is many times subjected.

HISTORICAL.

The outfit for making the observations under discussion was one designed for river and harbor currents or where the depth of water would not be likely to exceed 30 fathoms. It was taken from this class of work and placed on board the *Blake* for trial in the open sea while she was on one of her regular cruises in connection with the Gulf Stream investigation. Barring a few mishaps, which occurred mainly to the lowering cable and which could be prevented in future observations, the trial was entirely satisfactory and sustained the good record the instrument had previously made.

The *Blake* arrived on the working ground, a cross section between Jupiter Inlet, Florida, and Memory Rock on Little Bahama Bank, January 8, 1891. She spent the remainder of the month in this



THE RITCHIE-HASKELL DIRECTION CURRENT-METER.

locality, waiting mainly for good weather and obtaining only interrupted sets of observations on three stations, B^1, B^{1a}, and B^5 (see illustration No. 14). The wind blew nearly a gale the larger part of the time, keeping up such a sea that it was impossible to anchor. In the hope of finding more favorable weather in the Gulf of Mexico the *Blake* took her departure for that locality about February 1, spending the rest of the season in the eastern half. Although the weather conditions here were not all that could be desired, quite a number of current stations were occupied, at each of which good sets of observations were obtained.

For nearly half a century, data from actual observations on the tides and the currents of the Gulf of Mexico have been accumulating in the Survey, and from time to time they have been discussed and results published. A careful perusal of these reports reveals in nearly every instance that a satisfactory solution or conclusion could not be reached from the data in hand. There was an element usually attributed to wind and atmospheric pressure of which they had no measure. With our observations of last winter here to be discussed we are in the same condition; we lack data, but what we have should be of value, for it is out of a collection of such information that eventually must come a thorough knowledge of the circulation of this inland sea.

DISCUSSION OF OBSERVATIONS.

On the small chart of the Gulf of Mexico and parts of adjacent waters accompanying this report (illustration No. 14) are plotted the current stations occupied. The arrows, with their figures, indicate the mean velocity in knots per hour and the direction of the surface current.

Plotted on illustrations Nos. 15 to 21, in which time is taken as the abscissa and velocity as the ordinate, are the time-curves of velocity of stations X^4, Y^6, Y^3, Y^5, Z^3 and Z^{3a}, V and V^a and N^3 and N^4, together with the phases of the moon. The latter being represented by the usual symbols, its declination north or south by its position above or below the line of origin of ordinates, and its upper or lower transit by the subscript u or l.*

A careful study of all these time-curves of velocity reveals only in a few instances anything resembling a tidal flow. It is difficult, if not impossible, to pick out any recurring phenomenon that we can say belongs to the moon's transit or declination. It may be, however, and probably is the case, that we have no series of observations long enough, about twenty-six hours being the greatest at any one time on a station, to make any predictions or draw any conclusions, for during that time the winds and barometric gradients might have been such as to entirely overbalance normal conditions.

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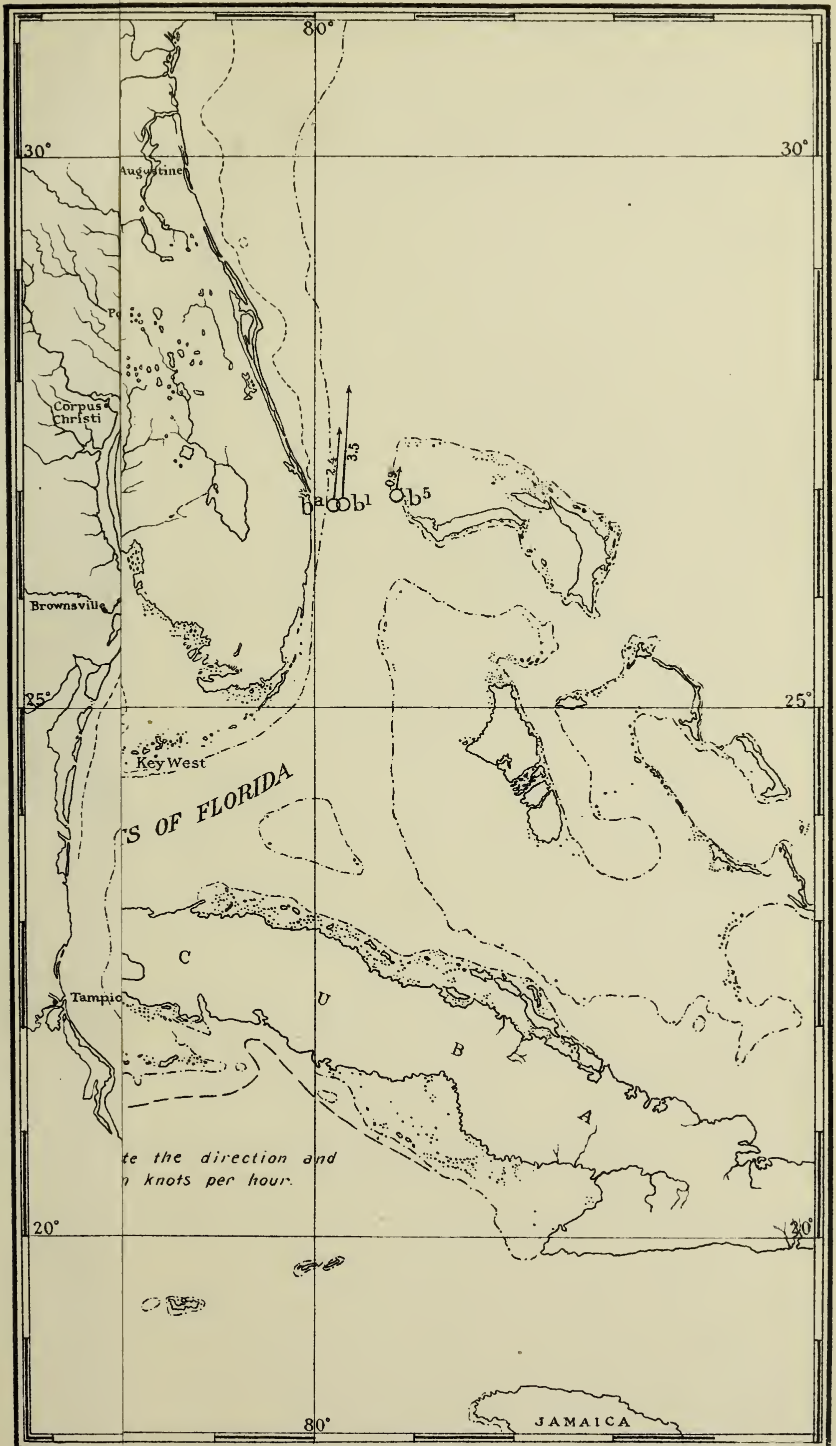
*These stations being characteristic of the whole group occupied, the others are purposely omitted.

The tide of the Gulf of Mexico, an interference one of three waves, that of the Gulf itself, that of the Caribbean Sea, and that of the Atlantic by the two entrances, the Channel of Yucatan and Straits of Florida, is not well understood, and we can hardly say that we know what should be expected. A glance at illustration No. 14 will surely convince the most skeptical that all the currents there shown could not be purely tidal or all taking place at the same time. To clear up this seeming mass of contradictions, the most logical method of procedure seems to be to consider all of those stations occupied in any one trip of the vessel at sea as a series by themselves, studying them in connection with the meteorological conditions prevailing over the Gulf at the time. Accordingly, to get our data before us for ready reference and a guide, Tables I and II have been compiled. In Table I will be found the date; the name of the current station with its latitude, longitude, and depth; the mean velocity and the direction of the surface current; the direction and velocity of the wind and the moon's phases. In Table II will be found for the period of observations in the Gulf of Mexico the direction and the velocity of the wind and the reading of the barometer at Brownsville, Corpus Christi, and Galveston, Tex.; New Orleans, La.; Mobile, Ala.; Pensacola, Tampa, and Key West, Fla.; data kindly furnished us by Prof. Harrington, Chief of the Weather Bureau, from their weather stations bordering the Gulf, together with similar observations made aboard the vessel at the current stations. Prof. Harrington has also kindly furnished us a complete file of the morning and evening weather map for Washington, D. C., that has aided materially in the discussion, giving at a glance a much better idea of the atmospheric circulation over the Gulf than can be obtained from the tabulated data. These, it is to be regretted, are too bulky to be here reproduced.

Before entering upon the discussion of the observations, it seems advisable to call attention to a few points, that we may thoroughly appreciate all the conditions. The Gulf on the twenty-fifth parallel is about 900 nautical miles long, and on the eighty-ninth meridian, or between the Mississippi Delta and the Peninsula of Yucatan, about 450 nautical miles wide, and has an average depth of 860 fathoms. From station N^1, nearly central in our group, it is about 700 nautical miles to Tampico, Mexico, 600 to Corpus Christi, 300 to Pensacola, 200 to Tampa, and 230 to Key West. These distances, it will be seen, are great enough to permit of very different atmospheric conditions in different parts of the Gulf, causing what we might call local disturbances, or the atmospheric gradients might be so marked as to involve the whole Gulf area. It is only the latter that can be at all considered here, and that imperfectly, as our data come from one side of the Gulf only.

Unequal atmospheric pressure and wind over any area are cause and effect, the greater the inequality of pressure the stronger the wind.


80°
30°
30°
Augustine
Corpus Christi
Brownsville
2.4
3.5
0.9
b a
b¹
b⁵
25°
25°
Key West
S OF FLORIDA
C
U
B
A
Tampic
te the direction and
n knots per hour.
20°
20°
80°
JAMAICA


CURRENT STATIONS
occupied by
STR. BLAKE
during
Jan., Feb., March and April
1891
GULF OF MEXICO
FLORIDA BANK
STRAITS OF FLORIDA
CAMPECHE BANK
YUCATAN CHAN
YUCATAN
CUBA
JAMAICA
Mobile
Pensacola
New Orleans
Galveston
Port Lavaca
Corpus Christi
Brownsville
Tampico
Vera Cruz
St. Augustine
Tampa
Key West
Havana
2000 fathom curve
1000 fathom curve
100 fathom curve
10 fathom curve
Note The arrows with their figures indicate the direction and the velocity of the surface current in knots per hour.
95°
90°
85°
80°
30°
25°
20°

Over a water surface unequal atmospheric pressure and wind both become causes, acting generally at an angle with each other to produce a current. The former is the equivalent of a head to be spent as a gravity force in the direction of the trend of the barometric gradient, while the latter acts by friction on the surface to produce a current in its direction. There is little or no information extant as to the current that any known velocity of wind and barometric gradient will produce, nor is there a definite enough relation between direction of wind and trend of barometric gradient to permit of making more than the general statement that the current should be in the direction of the resultant of the two forces.

In the following but little stress is laid on winds of less velocity than 10 miles per hour, unless blowing steadily from one direction for several days, or upon barometric gradients under three or four tenths of an inch in as many hundred miles.

Very frequently we see winds along our coast that raise the mean-sea level for a time a foot or more. A rise of one foot in the Gulf area north of the twenty-eighth parallel of latitude means enough water to maintain the Mississippi River discharging at its flood capacity of about two million cubic feet per second at its mouths for over seventeen days of twenty-four hours each. This will convey some idea of the quantity of water that may accumulate in any part of the Gulf under forces from a certain direction, and the current that would be created when such an accumulation was left to obey gravity or to such forces as accumulated it when coming from other directions.

TABLE I.—*Observations of currents in the Straits of Florida and in the Gulf of Mexico.*

Date.		Station.	Latitude.		Longitude.		Depth (fathoms).	Mean velocity and direction of surface current.		Direction and velocity of wind.		Moon.	
								Knots per hour.	Set.	Miles per hour.	Direction.	Phase.	Declination.
1891.			°	′	°	′							°
Jan.	10	B^5	26	56	79	10	244	·87	N.	4 to 12	SE.	New.	25 S.
Jan.	18 and 19	B^1	26	52	79	47	190	3·49	N.	10 to 18	*WSW. and NW.	First quarter.	15 N.
Jan.	20 and 21	B^{1a}	26	52	79	51	190	2·44	N.	4 to 12	E. and SE.	First quarter.	23 N.
Feb.	4, 5, and 6	X^2	23	06	85	05	1,045	·91	SE.	10 to 20	NE. by N. and E.	Last quarter.	25 S.
Feb.	6 and 7	X^3	23	22	86	16	1,860	·86	NW. by N.	10 to 15	SE. and S.	Last quarter.	25 S.
Feb.	8 and 9	X^4	23	58	87	09	404	1·97	NW.	10 to 20	SE. and SE. by S.	Last quarter and new.	20 S.
Feb.	10 and 11	Y^6	25	34	87	12	1,874	1·01	NNW.	15 to 18	SE. by E.	New.	11 S.
Feb.	11 and 12	Y^3	26	09	86	03	1,825	3·27	SE. by E.	5 to 15	E. by S. and SE.	New.	0
Feb.	23 and 24	Y^5	25	48	86	44	1,800	·57	SW. by S.	5 to 10	ENE. and E.	First quarter and full.	14 N.
Feb.	24	Y^4	25	57	86	26	1,750	1·29	SE. by E.	5 to 15	E. and ESE.	Full.	11 N.
Feb.	25	Y^{3a}	26	06	86	08	1,800	2·31	SE. by E.	10 to 15	SSE. and SW.	Full.	5 N.
Mar.	11 and 12	Y^2	26	23	85	33	1,800	·69	{ *SSE. SSW. }	5 to 15	SE. and S. by W.	New.	0
Mar.	19 and 20	Z^1	27	35	85	39	1,182	·88	NNW.	0		First quarter.	25 N.
Mar.	20 and 21	Z^2	27	22	86	15	1,760	1·89	NNW.	2 to 10	N. by W. to SW. by S.	First quarter.	22 N.
Mar.	21 and 22	Z^3	26	55	86	48	1,700	·95	{ *NE. ESE. }	10 to 18	W. and NNE.	First quarter.	18 N.
Mar.	22 and 23	V	26	25	86	27	1,700	2·09	ENE.	2 to 8	NNW. and N. by E.	First quarter.	15 N.
Mar.	31 and April 1	Z^{3a}	27	02	86	47	1,700	·75	ENE.	3 to 5	S., SW. and SSE.	Full.	25 S.
Apr.	1 and 2	V^a	26	34	86	15	1,750	1·63	NE.	10 to 15	SSE. and SSW.	Full and last quarter.	25 S.
Apr.	2 and 3	Y^{3b}	26	10	85	57	1,800	·48	{ *NE. W. by S. }	4 to 12	NW. by N.	Last quarter.	25 S.
Apr.	4 and 5	N^1	25	44	85	46	1,800	1·30	SW.	10 to 15	N. by W. and NNE.	Last quarter.	18 S.
Apr.	6 and 7	N^{2a}	25	11	85	33	1,800	2·09	SW. by S.	5 to 10	NE. and E. by S.	Last quarter.	6 S.
Apr.	7 and 8	N^3	24	55	85	06	1,850	3·08	NE. by E.	5 to 10	SE.	Last quarter.	2 S.
Apr.	8 and 9	N^4	24	32	84	49	2,000	1·74	NE.	10 to 18	E. and ESE.	New.	4 N.

* Directions between these limits reckoned in azimuth.

TABLE II.—*Observations of currents in the Gulf of Mexico.—Meteorological data.*

Date, 1891.	At Current Station.				Brownsville, Tex.			
	Wind, direction, and velocity (in miles per hour).		Barometer (aneroid).		Wind, direction, and velocity (in miles per hour).		Barometer reduced to sea.	
	8 a. m.	8 p. m.	8 a. m.	8 p. m.	8 a. m.	8 p. m.	8 a. m.	8 p. m.
Feb.								
1					N. 7	NE. 8	30·046	30·052
2					SE. 3	S. 12	29·999	29·904
3					S. 10	N. 16	·926	30·208
4		NE. by N. 11		30·13	NW. 12	N. 10	30·382	·298
5	NE. 14	ENE. 9	30·17	30·13	0	S. 9	·172	·003
6		SE. 4		29·98	S. 11	S. 19	29·917	29·723
7	SE. 9	SE. 9	29·93	29·93	SE. 2	E. 7	29·786	·737
8	SE. 11	SE. 15	29·93	30·02	S. 10	S. 9	·747	·720
9	SE. 14		30·06		0	N. 16	·850	30·227
10	SE. 9	SW. 1	30·12	30·14	N. 12	0	30·371	·214
11		E. 9		30·16	0	E. 6	·070	29·931
12	SE. 14	ESE. 2	30·14	30·10	S. 4	NW. 3	29·901	·939
13					N. 10	NW. 3	30·043	30·159
14					N. 5	N. 6	·151	·079
15					NW. 4	E. 4	·086	30·000
16					S. 6	SE. 9	29·963	29·868
17					S. 9	SE. 6	29·899	·870
18					S. 10	S. 9	·893	·844
19					S. 18	S. 16	·843	·754
20					S. 6	NE. 14	·737	·803
21					N. 12	NE. 10	·931	30·061
22					W. 7	E. 7	30·153	·004
23	ENE. 9	E. by N. 9	30·06	30·07	S. 10	S. 18	29·987	29·901
24		ESE. 4		29·98	S. 20	S. 20	·861	·704
25	SE. 11	SW. 11	29·92	29·82	NE. 12	E. 7	·828	·819
26					W. 13	NE. 7	30·292	30·391
27					E. 7	S. 13	·203	·114
28					S. 8	SE. 9	·156	·217
Mar.								
1					S. 7	SE. 9	·198	·124
2					S. 10	S. 21	·095	29·926
3					S. 29	S. 4	29·846	·874
4					N. 12	N. 6	30·011	·949
5					NW. 4	SE. 5	29·846	·741
6	SE. 9	SE. 9	30·02	29·95	S. 16	SE. 6	·701	·535
7					S. 12	E. 5	·570	·525

TABLE II.—*Observations of currents in the Gulf of Mexico.—Meteorological data*—Continued.

Date, 1891.	At Current Station.				Brownsville, Tex.			
	Wind, direction, and velocity (in miles per hour).		Barometer (aneroid).		Wind, direction, and velocity (in miles per hour).		Barometer reduced to sea.	
	8 a.m.	8 p.m.	8 a.m.	8 p.m.	8 a.m.	8 p.m.	8 a.m.	8 p.m.
Mar.								
8					NE. 16	NE. 5	30·003	30·109
9					N. 10	SE. 3	·347	·307
10					0	SE. 3	·204	·056
11		SSE. 15		30·01	SE. 7	SE. 8	29·933	29·870
12	S. by E. 15		30·00		E. 1	N. 16	·888	·980
13					N. 12	N. 12	30·320	30·294
14					NW. 7	E. 3	·313	·211
15					E. 16	N. 15	·063	·031
16					N. 10	N. 8	·246	·179
17					N. 4	SE. 6	·064	29·864
18					S. 4	SE. 6	29·869	·873
19		0		30·04	N. 20	N. 12	30·013	30·081
20	SW. 2	E. 7	30·04	30·04	N. 6	SE. 4	30·037	29·944
21	SW. 9	W. 11	29·95	29·92	S. 3	E. 6	29·986	30·031
22	NNE. 11	NNW. 2	29·92	29·94	E. 1	SE. 12	·943	29·859
23	N. by E. 4		29·91		SW. 10	SE. 7	·792	·692
24					SE. 9	E. 9	·714	·793
25					N. 12	N. 12	·899	·986
26					N. 6	SE. 7	30·127	30.028
27					S. 7	S. 10	·044	29·917
28					S. 10	S. 13	29·833	29·802
29					S. 17	S. 9	·789	·691
30					S. 5	S. 10	·745	·688
31	S. 4	SW. 1	29·98	29·98	NE. 15	E. 10	·924	·859
Apr.								
1	S. 4	S. 9	29·95	29·97	SW. 4	E. 10	·837	·891
2	SSW. 15	NW. 4	29.93	29·97	N. 24	N. 15	30·161	30·209
3	NNW. 14		29·98		N. 9	NE. 9	·294	·221
4		N. 9		30·11	N. 6	E. 6	30·395	·263
5	NNW. 4	NW. 17	30·14	30·17	NE. 6	E. 5	·397	·397
6		NE. 4		30·28	SE. 7	S. 13	·334	·123
7	ENE. 1	SE. 9	30·26	30·20	S. 10	S. 15	·044	29·959
8	SE. 9	ESE. 11	30·16	30·14	S. 13	S. 15	29·931	·871
9	E. 11		30·05		S. 12	SE. 7	·920	·972
10					S. 5	E. 9	·958	30·028

TABLE II.—*Observations of currents in the Gulf of Mexico.—Meteorological data*—Continued.

Date, 1891.	Corpus Christi, Tex.				Galveston, Tex.			
	Wind, direction, and velocity (in miles per hour).		Barometer reduced to sea.		Wind, direction, and velocity (in miles per hour).		Barometer reduced to sea.	
	8 a. m.	8 p. m.	8 a. m.	8 p. m.	8 a. m.	8 p. m.	8 a. m.	8 p. m.
Feb.								
1	NE. 6	E. 16	30·086	30·087	0	SE. 3	30·099	30·120
2	E. 6	SE. 12	·019	29·908	E. 12	S. 10	·067	29·936
3	NE. 8	N. 22	29·987	30·267	NW. 1	N. 28	·004	30·218
4	N. 12	NE. 18	30·431	·335	NE. 20	E. 8	·404	·361
5	NE. 9	NE. 5	·201	·008	SE. 8	SE. 12	·242	·079
6	SE. 6	S. 15	29·897	29·737	S. 8	SW. 9	29·947	29·785
7	0	S. 6	·794	·749	SW. 7	SE. 5	·807	·772
8	S. 9	E. 10	·742	·759	S. 13	SE. 10	·803	·827
9	N. 26	NW. 17	·999	30·278	NW. 24	NW. 28	·956	30·219
10	N. 12	N. 4	30·392	·278	NE. 24	0	30·341	·221
11	N. 6	N. 4	·105	29·952	SE. 2	0	·154	·024
12	S. 2	NW. 9	29·935	·967	S. 13	NW. 12	29·952	29·984
13	NW. 12	N. 7	30·107	30·156	NW. 12	NE. 12	30·059	30·132
14	NW. 10	NW. 10	·179	·100	NE. 16	N. 24	·150	·018
15	NW. 9	SE. 9	·062	29·991	NW. 9	0	29·970	·008
16	S. 9	SE. 18	29·964	·861	S. 4	S. 9	·989	29·909
17	S. 13	SE. 13	·899	·865	S. 8	SW. 6	·949	·921
18	S. 12	SE. 21	·913	·891	S. 3	SE. 12	·998	·968
19	SE. 15	SE. 21	·884	·769	SE. 14	SE. 13	·979	·884
20	SE. 13	N. 12	·728	·811	SE. 12	NE. 6	·839	·802
21	N. 9	N. 7	30·007	30·076	NW. 16	N. 12	·930	30·077
22	E. 18	SE. 19	·135	·035	E. 16	SE. 14	30·153	·102
23	SE. 6	SE. 24	29·987	29·883	SE. 9	SE. 8	·023	29·946
24	S. 17	SE. 24	·849	·701	S. 12	SE. 10	29·907	·782
25	N. 12	NW. 24	·873	·807	W. 6	NW. 10	·827	·804
26	N. 16	NE. 8	30·379	30·398	NW. 36	N. 18	30·288	30·378
27	SE. 10	SE. 19	·312	·104	S. 11	S. 13	·349	·170
28	S. 3	SE. 5	·189	·231	SW. 8	W. 6	·208	·253
Mar.								
1	SW. 4	SE. 19	·218	·114	NE. 3	S. 9	·258	·163
2	S. 6	SE. 29	·089	29·898	S. 10	S. 12	·118	29·976
3	S. 5	N. 24	29·862	30·009	SW. 9	NW. 22	29·919	30·009
4	N. 13	N. 13	30·097	29·979	NE. 24	NE. 22	30·094	·009
5	N. 8	E. 6	29·866	·769	E. 7	S. 12	29·862	29·757
6	NE. 6	E. 12	·748	·660	S. 4	S. 12	·810	·745
7	SE. 10	N. 30	·577	·698	S. 12	NW. 26	·630	·677

TABLE II.—*Observations of currents in the Gulf of Mexico.—Meteorological data*—Continued.

Date, 1891.	Corpus Christi, Tex.				Galveston, Tex.			
	Wind, direction, and velocity (in miles per hour).		Barometer reduced to sea.		Wind, direction, and velocity (in miles per hour).		Barometer reduced to sea.	
	8 a. m.	8 p. m.	8 a. m.	8 p. m.	8 a. m.	8 p. m.	8 a. m.	8 p. m.
Mar.								
8	NW. 18	N. 14	30·040	30·153	N. 26	NW. 20	29·935	30·089
9	N. 4	SE. 10	·390	·306	NW. 12	S. 6	30·327	·300
10	W. 7	SE. 10	·232	·075	SE. 10	SE. 16	·305	·138
11	S. 3	SE. 13	29·957	29·901	S. 6	SE. 8	·005	29·910
12	NE. 18	N. 23	·922	30·135	E. 11	N. 28	29·952	30·036
13	NW. 13	N. 10	30·369	·353	N. 24	N. 12	30·304	·313
14	N. 13	E. 25	·390	·282	E. 16	E. 13	·428	·368
15	E. 24	N. 24	·145	·146	NE. 18	NE. 22	·333	·203
16	N. 8	SE. 9	·293	·178	N. 16	NE. 3	·232	·155
17	0	E. 8	·082	29·875	NE. 3	SE. 4	·096	29·913
18	SE. 2	SE. 7	29·887	·896	S. 4	S. 12	29·912	·888
19	N. 36	N. 5	30·117	30·103	N. 18	N. 6	30·115	30·067
20	N. 4	E. 9	·052	29·936	N. 4	S. 6	·081	29·966
21	N. 11	SE. 5	·064	30·028	W. 8	NW. 2	·014	·996
22	S. 4	E. 30	29·952	29·841	NW. 4	SE. 14	·006	·889
23	NE. 24	E. 12	·818	·735	N. 4	E. 12	29·882	·812
24	SE. 9	SE. 9	·754	·830	SE. 12	SE. 13	·837	·834
25	N. 23	N. 12	·982	30·026	N. 23	N. 13	·985	·978
26	NW. 10	NW. 4	30·163	·011	N. 16	N. 20	30·055	30·001
27	0	SE. 17	·078	29·909	NW. 4	S. 12	·095	29·957
28	SE. 9	SE. 19	29·911	·818	S. 12	S. 12	29·911	·934
29	SE. 15	SE. 16	·794	·747	SE. 13	SE. 14	·867	·823
30	SE. 7	SE. 6	·760	·736	SE. 13	S. 12	·817	·732
31	N. 12	E. 24	·974	·878	NE. 12	SE. 12	·967	·901
Apr.								
1	E. 6	E. 6	·861	·900	E. 11	E. 5	·879	·884
2	N. 23	NW. 5	30·228	30·259	N. 24	NW. 9	30·166	30·181
3	NW. 9	SE 5	·341	·233	N. 24	N. 18	·302	·197
4	NE. 19	SE. 9	·354	·330	N. 22	N. 12	·371	·290
5	NE. 6	SE. 12	·479	·380	NE. 14	SW. 9	·443	·348
6	SW. 6	SE. 24	·363	·127	SW. 3	S. 19	·379	·194
7	S. 10	SE. 24	·049	29·930	S. 9	S. 12	·117	30·000
8	S. 11	SE. 18	29·954	·918	S. 8	SE. 20	·023	·001
9	SE. 12	SE. 8	·966	·998	SE. 8	SE. 12	·054	·039
10	SE. 3	SE. 10	30·090	30·059	S. 1	S. 9	·110	·090

TABLE II.—*Observations of currents in the Gulf of Mexico.—Meteorological data*—Continued.

Date, 1891.	New Orleans, La.				Mobile, Ala.			
	Wind, direction, and velocity (in miles per hour).		Barometer reduced to sea.		Wind, direction, and velocity (in miles per hour).		Barometer reduced to sea.	
	8 a. m.	8 p. m.	8 a. m.	8 p. m.	8 a. m.	8 p. m.	8 a. m.	8 p. m.
Feb.								
1	NW. 9	N. 4	30·060	30·131	S. 10	N. 3	30·038	30·149
2	E. 8	S. 9	·110	·026	N. 4	S. 10	·167	·071
3	S. 10	NE. 12	29·980	·126	SW. 11	N. 15	29.990	·099
4	NE. 20	NE. 10	30·390	·373	N. 20	N. 9	30·384	·380
5	NE. 3	SE. 8	·317	·182	NE. 6	SE. 14	·385	·239
6	SE. 8	S. 10	·018	29·851	N. 4	S. 12	·090	29·862
7	SW. 9	S. 10	29·820	·839	W. 8	0	29·832	·860
8	S. 6	S. 10	·918	·946	S. 6	S. 12	·952	·990
9	S. 16	S. 15	·951	·994	S. 12	S. 12	·992	30·010
10	N. 18	NE. 5	30·207	30·207	N. 20	N. 12	30·187	·194
11	NE. 10	E. 9	·189	·116	N. 5	N. 3	·213	·134
12	SE. 12	S. 12	·052	·010	S. 8	S. 6	·089	·050
13	E. 6	NE. 9	·056	·131	0	N. 4	·075	·131
14	NE. 14	NE. 16	·164	·138	N. 12	NE. 11	·216	·186
15	SE. 24	SE. 8	·065	·065	SE. 11	SE. 20	·191	·083
16	S. 4	SW. 5	·009	29·975	S. 11	S. 10	·044	29·985
17	S. 5	SW. 5	·001	·978	NW. 4	S. 9	·040	·982
18	S. 6	SE. 8	·087	30·085	S. 6	S. 8	·101	30·116
19	SE. 9	SE. 12	·105	·033	SE. 6	SE. 9	·149	·097
20	SE. 14	S. 20	29·939	29·824	SE. 12	S. 15	·010	29·867
21	N. 1	NE. 22	·824	30·024	SW. 6	N. 16	29·862	29·981
22	NE. 13	E. 4	30·219	·183	N. 8	N. 7	30·210	30·170
23	NE. 8	SE. 15	·131	·069	E. 5	SE. 4	·168	·088
24	SE. 10	S. 11	·022	29·898	SE. 6	S. 15	·060	29·915
25	SW. 9	S. 9	29·810	·677	S. 5	SW. 12	29·838	·662
26	W. 20	NW. 19	·961	30·285	NW. 12	NW. 12	·853	30·227
27	NE. 12	SE. 8	30·433	·325	NE. 8	S. 7	30·433	·346
28	SE. 12	SW. 11	·286	·215	E. 7	S. 12	·355	.214
Mar.								
1	NE. 4	SW. 12	·278	·204	N. 8	NE. 2	·289	·211
2	S. 5	S. 12	·204	·077	S. 4	S. 15	·215	·078
3	S. 7	S. 10	29·986	29·969	S. 12	S. 6	29·993	29·965
4	NE. 16	NE. 12	30·097	30·103	N. 15	NE. 4	30·135	30·114
5	E. 10	S. 19	·024	29·894	E. 6	SE. 7	·085	29·970
6	S. 8	SE. 9	29·910	·850	S. 10	E. 8	29·925	·921
7	SE. 19	S. 22	·770	·673	S. 14	S. 15	·864	·758

TABLE 11.—*Observations of currents in the Gulf of Mexico.—Meteorological data*—Continued.

Date. 1891.	New Orleans, La.						Mobile, Ala.							
	Wind, direction, and velocity (in miles per hour).				Barometer reduced to sea.		Wind, direction, and velocity (in miles per hour).				Barometer reduced to sea.	
	8 a. m.		8 p. m.		8 a. m.	8 p. m.	8 a. m.		8 p. m.		8 a. m.	8 p. m.
Mar.												
8	NW.	16	W.	12	29·748	29·929	S.	12	N.	9	29·723	29·826
9	NW.	18	N.	12	30·231	30·301	NW.	12	NW.	11	30·140	30·284
10	NE.	12	E.	5	·384	·252	NE.	12	SE.	5	·412	·270
11	NE.	9	NE.	12	·131	29·961	NE.	5	NE.	8	·178	29·961
12	N.	4	SE.	4	29·973	·915	N.	7	S.	11	29·976	·900
13	NW.	22	N.	12	30·145	30·242	N.	20	N.	8	30·076	30·189
14	N.	12	N.	7	·424	·381	NW.	6	N.	8	·382	·390
15	NE.	8	NE.	12	·420	·291	NE.	11	SW.	4	·425	·332
16	NE.	26	NE.	13	·115	·109	N.	8	N.	11	·258	·100
17	NE.	2	E.	6	·080	29·931	N.	10	SW.	5	·071	29·942
18		0	SE.	7	29·972	·924	NE.	2	S.	6	29·960	·922
19	SW.	5	NW.	7	30·017	30·004	SW.	8	S.	8	30·024	·991
20	NE.	8	SE.	8	·115	29·998	N.	6	S.	8	·102	·992
21	W.	5	NW.	15	29·971	·892	NW.	6	NW.	5	29·910	·831
22	N.	6	N.	2	30·010	·955	NW.	10		0	·973	·904
23	NE.	6	NE.	7	29·935	·907		0	SW.	10	·953	·914
24	SE.	7	E.	8	·959	·913	NE.	3	S.	7	·930	·933
25	SE.	6	SE.	8	·932	·852	SE.	5	SE.	20	·968	·937
26	W.	10	W.	12	·882	·859	SW.	4	SW.	10	·801	·783
27	W.	8	W.	8	30·033	·911	NW.	15	NW.	4	·968	·879
28	W.	4	S.	12	29·992	·936	NE.	6	S.	8	·996	·951
29	S.	4	SE.	10	30·013	·982	E.	2	S.	7	30·053	30·033
30	S.	17	S.	12	29·943	·826	SE.	8	S.	6	·012	29·862
31	NW.	20	E.	2	·940	·931	NW.	10	NW.	5	29·862	·917
Apr.												
1	E.	6	N.	7	·931	·827	NE.	2	SE.	12	·968	·872
2	NW.	11	NW.	20	·957	30·049	NW.	6	NW.	12	·897	30·003
3	N.	12	NW.	11	30·198	·092	NW.	9	NW.	8	30·124	·042
4	NE.	12	N.	8	·278	·244	NW.	12	N.	11	·240	·243
5	NE.	8	NW.	16	·374	·308	NW.	9	N.	9	·355	·285
6	SE.	5	S.	12	·407	·240	W.	2	S.	8	·390	·237
7	SE.	5	S.	14	·196	·088	SW.	4	S.	7	·235	·132
8	S.	6	S.	10	·134	·126	S.	3	S.	9	·170	·166
9	SE.	12	SE.	10	·144	·138	SE.	5	S.	8	·212	·196
10	SE.	10	SW.	2	·132	·124	SE.	8	S.	8	·177	·140

TABLE II.—*Observations of currents in the Gulf of Mexico.—Meteorological data*—Continued.

Date, 1891.	Pensacola, Fla.						Tampa, Fla.					
	Wind, direction, and velocity (in miles per hour).				Barometer reduced to sea.		Wind, direction, and velocity (in miles per hour).				Barometer reduced to sea.	
	8 a. m.		8 p. m.		8 a. m.	8 p. m.	8 a. m.		8 p. m.		8 a. m.	8 p. m.
Feb.												
1	SW.	8	N.	9	30·043	30·136	SE.	4	W.	6	30·184	30·194
2	E.	7	S.	10	·147	·077	NE.	1	W.	2	·237	·173
3	SW.	6	N.	11	·012	·075	SE.	4	SW.	4	·122	·085
4	N.	19	NE.	9	·335	·381	NW.	11	N.	10	·187	·278
5	NE.	16	NE.	9	·368	·233	NE.	10	NE.	4	·327	·242
6	E.	8	S.	8	·077	29·888	N.	1	W.	1	·159	·023
7	SW.	19	SW.	10	29·839	·866	SE.	1	SW.	3	29·992	·015
8	SW.	5	SE.	9	·965	30·014	SE.	3		0	30·073	·112
9	S.	9	S.	9	30·027	·031	SE.	2	SW.	3	·171	·149
10	N.	16	N.	14	·132	·190	S.	7	SW.	3	·182	·156
11	NE.	14	SE.	8	·198	·148	SW.	2	W.	6	·192	·176
12	S.	11	SE.	9	·112	·076	SE.	4	W.	1	·210	·150
13	NE.	7	NE.	11	·057	·122	E.	3	W.	6	·148	·135
14	NE.	12	E.	15	·197	·204	NE.	4	NE.	12	·219	·209
15	E.	21	SE.	16	·193	·130	E.	10	E.	10	·251	·235
16	SE.	7	SW.	14	·066	29·998	SE.	11	SW.	6	·220	·138
17		0	SW.	7	·030	·994	S.	6	SW.	2	·155	·122
18	SW.	4	SE.	6	·109	30·138	E.	2	W.	6	·192	·180
19	SE.	9	SE.	10	·174	·104	SE.	1	E.	4	·249	·166
20	SE.	21	S.	14	·036	29·889	E.	4	SW.	5	·158	·041
21	N.	9	N.	12	29·847	·938	SE.	11	SW.	1	29·968	29·963
22	N.	16	NE.	12	30·195	30·162	NE.	3	NE.	11	30·060	30·125
23	E.	16	SE.	7	·186	·112	NE.	6	NE.	8	·134	·100
24	SE.	19	SE.	14	·086	29·936	NE.	8	E.	4	·104	30·000
25	SW.	9	SW.	15	29·827	·681	E.	4	SW.	6	29·952	29·838
26	W.	12	NW.	9	·806	30·210	SW.	15	NW.	13	·793	30·045
27	NE.	20	SE.	9	30·526	·342	N.	7	NE.	6	30·373	·362
28	SE.	17	SW.	11	·362	·250	N.	6	NW.	4	·424	·325
Mar.												
1	N.	6	SW.	14	·272	·230	N.	4	NW.	4	·328	·264
2	E.	3	SW.	12	·222	·101	NE.	1	NW.	5	·271	·193
3	S.	10	SW.	10	·019	29·973	E.	1	SW.	4	·169	·118
4	N.	19	NE.	9	·069	30·105	S.	4	NW.	1	·098	·105
5	E.	18	SE.	6	·085	29·988	E.	4	W.	3	·152	·091
6	S.	10	SE.	12	29·947	·930	SE.	1	W.	1	·070	·005
7	SE.	17	SE.	16	·853	·784	SE.	4	SW.	5	·013	29·946

TABLE II.—*Observations of currents in the Gulf of Mexico.—Meteorological data*—Continued.

Date. 1891.	Pensacola, Fla. Wind, direction, and velocity (in miles per hour). 8 a. m.		Barometer reduced to sea. 8 a. m.		Tampa, Fla. Wind, direction, and velocity (in miles per hour). 8 a. m.		Barometer reduced to sea. 8 a. m.	
	8 a. m.	8 p. m.	8 a. m.	8 p. m.	8 a. m.	8 p. m.	8 a. m.	8 p. m.
Mar.								
8	S. 18	N. 16	29·752	29·832	SE. 10	S. 7	29·970	29·943
9	NW. 16	NW. 9	30·114	30·271	S. 8	NW. 7	·998	30·131
10	NE. 17	NE. 7	·388	·268	N. 11	NE. 12	30·297	·231
11	NE. 10	NE. 9	·178	29·951	NE. 10	SE. 11	·198	·052
12	NE. 6	SE. 5	29·969	·900	SE. 11	SE. 3	·013	30·000
13	NW. 24	NW. 9	·998	30·175	S. 9	NW. 9	29·963	·012
14	N. 6	N. 9	30·368	·372	N. 6	NW. 6	30·277	·292
15	NE. 17	N. 2	·405	·313	NE. 11	E. 9	·365	·273
16	NE. 16	N. 16	·219	·084	NE. 12	E. 8	·181	29·939
17	NE. 9	SW. 4	·033	29·947	NE. 6	N. 6	29·904	·890
18	E. 6	SW. 6	29·956	·930	NW. 6	W. 5	·945	·979
19	W. 5	SW. 9	30·022	30·009	E. 4	W. 2	30·072	30·060
20	NE. 7	SW. 7	·090	29·994	N. 2	SW. 4	·102	·155
21	SW. 2	NW. 12	29·890	·801	S. 4	W. 11	29·984	29·821
22	NW. 10	NW. 7	·946	·900	NW. 4	W. 5	·910	·851
23	NE. 6	SW. 7	·928	·887	W. 3	W. 3	·900	·874
24	NE. 8	SE. 5	·919	·932	NW. 4	W. 4	·964	·955
25	SE. 14	NE. 12	·987	·951	NE. 4	W. 3	30·056	30·030
26	SW. 15	SW. 17	·814	·775	SE. 10	SE. 9	·028	29·902
27	NW. 17	W. 6	·948	·880	W. 10	W. 8	29·912	·908
28	N. 9	W. 5	·990	·955	NW. 4	W. 5	·957	·989
29	E. 7	SE. 3	30·051	30·036	NW. 4	NW. 4	30·088	30·047
30	SE. 17	SE. 23	·006	29·891	NE. 6	NE. 1	·126	·043
31	SW. 20	0 0	29·866	·905	SE. 12	SW. 10	·020	·013
Apr.								
1	E. 7	E. 11	·962	·885	S. 4	SW. 4	·033	·007
2	NW. 10	NW. 20	·886	·963	SW. 8	W. 6	29·970	29·910
3	NW. 4	NW. 6	30·118	30·021	NW. 11	NW. 6	30·000	30·018
4	NE. 13	NW. 9	·210	·218	N. 10	NW. 3	·103	·160
5	N. 12	N. 9	·328	·281	N. 8	W. 5	·252	·176
6	0	W. 12	·389	·247	NE. 11	NW. 6	·383	·313
7	N. 5	SW. 5	·236	·141	SW. 1	W. 4	·327	·241
8	SW. 2	SE. 9	·173	·181	NE. 5	N. 6	·283	·219
9	SE. 10	SE. 11	·218	·208	E. 3	E. 8	·291	·243
10	SE. 12	E. 21	·194	·193	E. 6	W. 6	·289	·229

TABLE II.—*Observations of currents in the Gulf of Mexico.—Meteorological data*—Continued.

Date. 1891.	Key West, Fla. Wind, direction, and velocity (in miles per hour). 8 a. m.	Key West, Fla. Wind, direction, and velocity (in miles per hour). 8 p. m.	Barometer reduced to sea. 8 a. m.	Barometer reduced to sea. 8 p. m.	Date. 1891.	Key West, Fla. Wind, direction, and velocity (in miles perhour). 8 a. m.	Key West, Fla. Wind, direction, and velocity (in miles perhour). 8 p. m.	Barometer reduced to sea. 8 a. m.	Barometer reduced to sea. 8 p. m.
Feb. 1	SE. 6	E. 8	30·167	30·168	Mar. 8	SE. 9	SE. 6	29·980	29·988
2	E. 8	SE. 8	·194	·140	9	SE. 8	SE. 12	30·055	30·123
3	SE. 7	SE. 5	·105	·088	10	NE. 13	E. 10	·200	·136
4	NE. 6	NE. 14	·126	·174	11	SE. 12	SE. 10	·149	·053
5	NE. 24	E. 14	·228	·156	12	SE. 12	SE. 4	·058	·016
6	NE. 9	NE. 6	·116	·007	13	S. 6	NW. 12	·024	·005
7	SE. 6	SE. 3	29·983	29·999	14	N. 28	NE. 16	·148	·185
8	SE. 8	E. 9	30·064	30·089	15	NE. 18	E. 12	·259	·211
9	SE. 12	E. 12	·141	·138	16	E. 14	SE. 6	·142	·005
10	SE. 4	SE. 5	·192	·134	17	SW. 15	NW. 12	29·927	29·919
11	E. 9	E. 12	·179	·150	18	NW. 5	NW. 12	·974	·986
12	E. 12	SE. 16	·176	·123	19	SE. 8	SE. 2	30·068	30·068
13	SE. 8	E. 8	·125	·116	20	SE. 3	SE. 2	·107	·070
14	E. 5	E. 13	·156	·139	21	SW. 4	W. 22	·048	29·954
15	E. 24	E. 24	·191	·178	22	NW. 22	NW. 14	29·962	·901
16	SE. 16	E. 12	·179	·128	23	NW. 18	NW. 12	·924	·882
17	SE. 8	E. 9	·156	·120	24	NE. 9	NE. 2	·933	·951
18	SE. 12	E. 19	·146	·132	25	NE. 12	E. 12	30·013	30·001
19	E. 12	E. 19	·204	·119	26	SE. 12	SE. 12	29·997	29·953
20	E. 10	SE. 12	·115	·036	27	S. 2	NW. 14	·946	·908
21	SE. 9	SE. 5	·021	29·983	28	NW. 13	NW. 13	·975	·981
22	N. 20	NE. 8	·120	30·071	29	NE. 14	0	30.077	30·041
23	NE. 3	NW. 14	·092	·046	30	E. 13	SE. 10	·095	·031
24	N. 5	N. 5	·064	·001	31	SE. 16	SE. 5	·036	·028
25	E. 1	E. 3	29·971	29·905	Apr. 1	S. 7	SE. 5	·056	·028
26	SW. 13	NW. 26	·918	30·044	2	SE. 5	SW. 5	·026	29·992
27	N. 25	NE. 20	30·275	·292	3	NW. 9	N. 16	29·986	30·012
28	NE. 14	NE. 14	·308	·268	4	N. 8	N. 24	30·086	·134
Mar. 1	NE. 12	NE. 6	30·281	·252	5	N. 20	NW. 12	·200	·193
2	NE. 13	NE. 4	·253	·191	6	N. 28	NE. 8	·343	·312
3	NE. 12	SE. 5	·176	·133	7	NE. 12	E. 8	·309	·209
4	SE. 3	SE. 4	·120	·116	8	E. 13	E. 12	·203	·196
5	E. 4	E. 8	·121	·068	9	E. 14	E. 20	·213	·203
6	SE. 6	SE. 6	·050	·013	10	E. 9	E. 7	·239	·178
7	SE. 9	E. 8	·037	29·959					

At Station B^5, near Memory Rock, occupied January 10—change of last quarter to new moon, 25° south declination—was found a current of from 0·7 to 1·0 knot per hour, setting north, the wind in the interval blowing from the southeast with a velocity varying from 4 to 12 miles per hour.

At Station B^1, off Jupiter Inlet, Fla., occupied January 18 and 19—moon in first quarter, 15° north declination—was found a current of from 2·9 to 3·9 knots per hour, setting north, the wind in the interval blowing from directions between west-southwest and northwest with a velocity varying from 10 to 18 miles per hour.

At Station B^{1a}, off Jupiter Inlet, Fla., occupied January 20 and 21—moon in first quarter, 23° north declination—was found a current of from 2·0 to 3·0 knots per hour, setting north, the wind in the interval blowing from directions between east and southeast with a velocity varying between 4 and 12 miles per hour.

The current at these three stations is in keeping in velocity with that found by Lieut. J. E. Pillsbury, U. S. N., when in command of the *Blake*, on the cross-section between Fowey Rocks and Gun Cay, 75 miles further south. The sets of observations are too short to determine any diurnal or semi-diurnal variation in the flow or any influence due to the moon's declination.

In the first series of current stations in the Gulf are X^2, X^3, X^4, Y^6, and Y^3, occupied in order named, for an interval of about 26 hours each between February 4 and 12. The phases of the moon during this time were, on the 4th in last quarter traveling south, reaching its maximum declination at noon on the 6th, changing to new moon the morning of the 9th, and reaching a north declination of 2° by the afternoon of the 12th.

At Station X^2 was found a current of from 0·5 to 1·3 knots per hour, setting in all directions between northeast (via east) and west, the wind in the interval blowing from directions between northeast by north and east with a velocity of 15 to 20 miles per hour.

At Station X^3 was found a current of from 0·5 to 1·3 knots per hour, setting northwest by north, the wind in the interval blowing from directions between southeast and south with a velocity of 10 to 15 miles per hour.

At Station X^4 was found a current of from 1·5 to 2·3 knots per hour, setting northwest by north, the wind in the interval blowing from directions between southeast and southeast by south, with a velocity of 10 to 20 miles per hour.

At Station Y^6 was found a current of from 0·8 to 1·3 knots per hour, setting north by west, the wind in the interval blowing first from southeast by east with a velocity of 15 to 18 miles per hour, gradually veering to west, where it died out, finally appearing in same quarter and backing to east-southeast, reaching a velocity of 10 to 12 miles per hour.

On observations of currents with the direction-current meter—Continued.

At Station Y^3 was found a current of from 2·7 to 3·9 knots per hour, setting southeast by east, the wind in the interval blowing from directions between east by south and southeast with a velocity of 5 to 15 miles per hour.

An examination of the weather data in Table II shows that while observations on X^2 were in progress on the 4th, 5th, and 6th of February the velocity and direction of the wind at Key West was the same as found at the current station. A "norther" of considerable force made its appearance in the northwest quarter of the Gulf on the afternoon of the 3d, seen in the northeast quarter on the morning of the 4th, which lasted about thirty-six hours, the barometer in the meantime indicating a sharp rise at all points excepting Tampa, Key West, and the current station. The resultant of these forces would take about the direction shown by the current at X^2, and its baffling tendency is probably due to whichever force was temporarily the stronger. While observations on X^3 were in progress on the 6th and 7th, the wind along the northern borders of the Gulf was in the quadrant between southeast and southwest, there having been a gradual veering from the north on the 3d and 4th to this position. The wind at the current station was in the same quarter, showing the movement to have been common over the Gulf area. The barometric gradient in the meantime had been changing with the wind till its trend on the evening of the 7th was about northwest. The current at X^3 was about in the direction of the resultant of these forces toward an area that by the conditions just previous had been made a *low* water surface. X^4 was occupied on the 8th and 9th, the wind of considerable force was in the southeast, where it had been while the previous station was being occupied. The same is true of the wind along the northern borders of the Gulf, excepting in Texas, where a "norther" appeared on the 9th, but too late to have any influence at this station. The trend of the barometric gradient had remained practically unchanged, and the current here, as at X^3, was moving about in the direction of the resultant of it and the wind. At Y^6, occupied between the morning of the 10th and the 11th, the wind was practically in the quarter it had been, but shows by its having veered to the west and died out for a short interval that there had been a change in the atmospheric circulation over the Gulf, caused probably by the "norther" that appeared in Texas on the 9th, and spread over the Gulf on the 10th, becoming variable winds and of but little consequence by the 11th. The barometric gradient, gentle in slope, had gradually revolved via south from its previous northwest trend to an east one. The current was moving under the same forces as maintained X^3 and X^4, only in a little different direction, due probably to the earlier disturbances in the northwest quarter of the Gulf, or it may be that the accumulation of *head* in that locality was greater than further to the eastward, and it was taking the direction of least resistance.

Y^3 was occupied between the evenings of the 11th and the 12th, the current, a strong one, was setting directly into the wind that was about the same in velocity and direction as that at Key West, and almost opposite to that prevailing along the Texas coast. The barometric gradient, a gentle one, had revolved from its eastward trend of the 10th to southwest by the morning and west by the evening of the 11th, where it remained till the close of observations on the station. If we grant that it takes some little time for the inertia of such a moving mass of water to be overcome, this current can be accounted for by the "norther" of the 9th and 10th and the accumulated *head* in the northwest quarter, the two forming a force sufficient to maintain for a time this stream against the opposing forces existing at the actual time of observation. It is unfortunate that the vessel did not remain at this station longer in order to find out if the current did not soon slacken and perhaps entirely shift in direction.

The next series of observations was made on current stations Y^5, Y^4, and Y^{3a}, between February 23 and 25. These stations, as a glance at illustration No. 14 will show, are on a line joining Y^6 and Y^3, which belong to the series just preceding. The moon was changing from full moon (February 23) towards last quarter with a declination north of from 15° to 3°.

At Y^5 was found a current of from 0·3 to 0·8 knots per hour, setting southwest by south, the wind in the interval blowing from directions between east-northeast and east with a velocity of 5 to 10 miles per hour.

At Y^4 was found a current of from 1·1 to 1·4 knots per hour, setting south by east, the wind in the interval blowing from directions between east and east-southeast with a velocity of 5 to 15 miles per hour.

At Y^{3a} was found a current of from 2·0 to 2·4 knots per hour, setting southeast, the wind in the interval blowing for a short time from south-southeast with a velocity of 10 to 15 miles per hour, when it veered to the southwest without change in strength.

An examination of the meteorological data in Table II shows that while observations on Y^5 were in progress the wind and its direction at Tampa was the same as that at the current station, not strong at either place; nor was the current, which seems to have been moving in the direction of the resultant between the wind and the barometric gradient. The time curve of velocity of this station shows a gradual decrease in strength from beginning to end of observations, and had the vessel remained a few hours longer a change in direction to that seen at Y^4 might have occurred; for, closing observations on Y^5 at 4 a. m. of the 24th, the vessel went immediately to Y^4, beginning observations there by 8 a. m., an interval of only four hours. At Y^4 the current was running almost directly into the wind and about parallel to the isobars. At Y^{3a} the current was running nearly against the wind for a time, or until it veered to the southwest, and directly up the bar-

On observations of currents with the direction-current meter—Continued.

ometric gradient. By going back and examining the weather data, it will be seen that the wind and barometric gradients were such as to crowd the water into the northern area of the Gulf from the 16th to the 18th, and into the northwest quarter from the 18th to the 20th, followed by a period between the 20th and 22d when the wind and barometric gradients were light, but in favor of a northwest movement from Key West to Tampa and a southerly movement from Pensacola to Brownsville. The current at Y^5 was the last of the movement of the forces crowding the water into the northwest quadrant where a sufficient head had accumulated to maintain even against forces of considerable resistance the current at Y^4 in the direction it was taking, until equilibrium along the Florida coast was established, when the direction was changed to that seen at Y^{3a}.

The next series consists of observations on one station only, Y^2, occupied March 11 and 12, a storm preventing further work. At Y^2 was found a current of from 0·4 to 1·0 knot per hour setting toward points between south-southeast and south-southwest, the wind in the interval blowing from directions between southeast and south by west, with a velocity of 5 to 15 miles per hour. It was new moon, zero declination, the same phase as when Y^3 was occupied and such a strong current found. An examination of the weather data in Table II shows this direction of the current to be in keeping with that of the resultant of the wind as observed at the land stations and the barometric gradient, although in opposition to the wind at the station itself.

The next series of stations, Z^1, Z^2, Z^3, and V, were occupied between March 19 and 23; the moon during the interval was in first quarter and in from 25° to 12° north declination.

At Z^1 was found a current of from 0·6 to 1·1 knots per hour setting north-northwest, the wind in the interval amounting to nothing and the sea smooth.

At Z^2 was found a current of from 0·7 to as swift as 3·0 knots per hour, setting northwest, the wind in the interval increasing in velocity from about 2 to 10 miles per hour, and veering from north by west to southwest by south.

At Z^3 was found a current of from 0·5 to 1·9 knots per hour, setting towards points between northeast and east-southeast, the wind in the interval, with a velocity of 10 to 18 miles per hour, blowing first from the west, then veering to north-northeast.

At V was found a current of from 1·1 to 2·7 knots per hour, setting east-northeast, the wind in the interval blowing from directions between north-northwest and north by east with a velocity of 2 to 8 miles per hour.

An examination of the weather data in Table II shows the Gulf to have been in a state of quiet from the 17th to the 19th, when a "norther" of considerable force, but of short duration, made its appearance in the vicinity of Corpus Christi. From the 20th to 23d, inclusive, the winds

appear to have been local, variable in direction, and only at one or two points showing any marked velocity. There was no general movement or circulation common to the Gulf area. There is a little indication that at Z^3 and V the current might have been taking the direction it did under the influence of a wind and barometric gradient that existed just previous to occupying these stations, as shown by the conditions at Z^2 and the first part of Z^3. It would seem, therefore, that Z^1 and Z^2 were observed under nearly normal conditions, and that the drift and set at these stations is what may be expected under similar phases of the moon. An examination of the time curve of velocity of Z^2 shows a well-defined maximum in velocity occurring about three hours previous to the moon's transit.

The next and last series of stations—Z^{3a}, V^a, Y^{3b}, N^1, N^{2a}, N^3, and N^4—were occupied between March 31 and April 9. The moon during the interval was full, in last quarter, and reached new moon; in declination, from maximum or 25° south to 13° north.

At Z^{3a}, within 8 nautical miles of Station Z^3, was found a current of from 0·4 to 1·0 knot per hour, setting east-northeast, the wind in the interval blowing first with a velocity of about 3 to 5 miles per hour from the south, veered to the southwest, and died out; later, appearing in the south-southeast and reaching about the same velocity.

At V^a was found a current of from 0·7 to 2·2 knots per hour setting northeast, the wind in the interval blowing from directions between south-southeast and south-southwest with a velocity of 10 to 15 miles per hour.

At Y^{3b} was found a current of from 0·3 to 0·6 knot per hour setting towards points between northeast (in azimuth via east) and west by south, the wind in the interval blowing from northwest by north with a velocity of 4 to 12 miles per hour.

At N^1 was found a current of from 0·9 to 1·7 knots per hour setting southwest, the wind in the interval blowing from directions between north by west and north-northeast with a velocity of 10 to 15 miles per hour.

At N^{2a} was found a current of from 0·9 to 2·5 knots per hour setting southwest by south, the wind in the interval blowing from directions between northeast and east by south with a velocity of 5 to 10 miles per hour.

At N^3 was found a current of from 2·0 to 3·4 knots per hour setting northeast by east, the wind in the interval blowing from directions between southeast by east and south-southeast with a velocity of 5 to 10 miles per hour.

At N^4 was found a current of from 1·2 to 2·1 knots per hour setting northeast, the wind in the interval blowing from directions between east and east-southeast with a velocity of 10 to 18 miles per hour.

The weather map for the morning of March 28 shows an area of high barometer central over the Mississippi delta. Twenty-four hours

On observations of currents with the direction-current meter—Continued.

later it had reached a position central over Florida, and the resultant of wind and barometric gradient was toward the northwest quarter of the Gulf. These forces continued till sometime between the evening of the 30th and the morning of the 31st, when the wind shifted, showing various directions, and the barometric gradient changed to a trend about northeast. From these facts it seems quite reasonable to suppose that there was an accumulation of water in the northwest quarter of the Gulf, forming a head that with this new position of the barometric gradient was the cause for the current at Z^{3a} and V^{a}.

Between the morning of the 1st and the morning of the 2d of April, an area of low barometer, extending about north and south, passed northeasterly across the Gulf, followed by a steep barometric gradient trending to the northeast. The resultant of this gradient and the wind was a force to add to the accumulation of water on the Florida coast, placed there through the movement at Z^{3a} and V^{a}, and hold in check the current at Y^{3b}, which was by this time being backed by gravity. A further examination shows a shift of wind and barometric gradient to such a quarter as to let out this last accumulation, and undoubtedly it was the cause for the current at N^{1} and N^{2a}. On April 5 there was an area of high barometer central on the western borders of the Gulf, which by the 6th was off the Mississippi delta, and by the 7th over southern Florida. There was little or no wind with this *high* and it does not seem possible that it was sufficient to cause a *low* in the water surface along the Florida coast that would engender the current seen at N^{3} and N^{4} on the 7th, 8th, and 9th, and it may be that this movement was one caused by forces in the southwest quarter of the Gulf which we know not of.

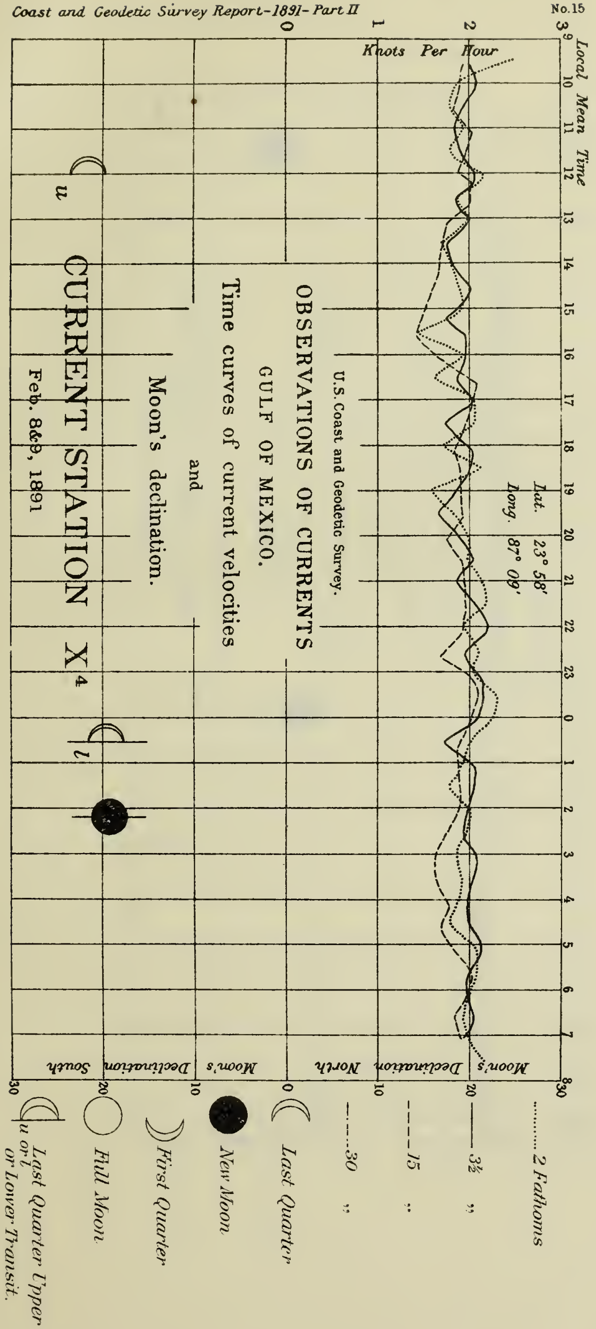
At times in the foregoing discussion it has occurred to me that possibly we were "reckoning without our host," for our meteorological data are confined to the coast of the United States, leaving about one half of the periphery of the Gulf from which we have no information. We have no tidal observations from any quarter which would be of great value in confirming the heaping up or driving out of the water at any particular point or time, according as the resultant of wind and barometric gradient was on or off shore. But certainly there can be no question that the observations we have go to prove that the atmospheric pressure and winds can be such as to set at naught the normal circulation of the Gulf and create and maintain currents of surprising velocity for a considerable period of time.

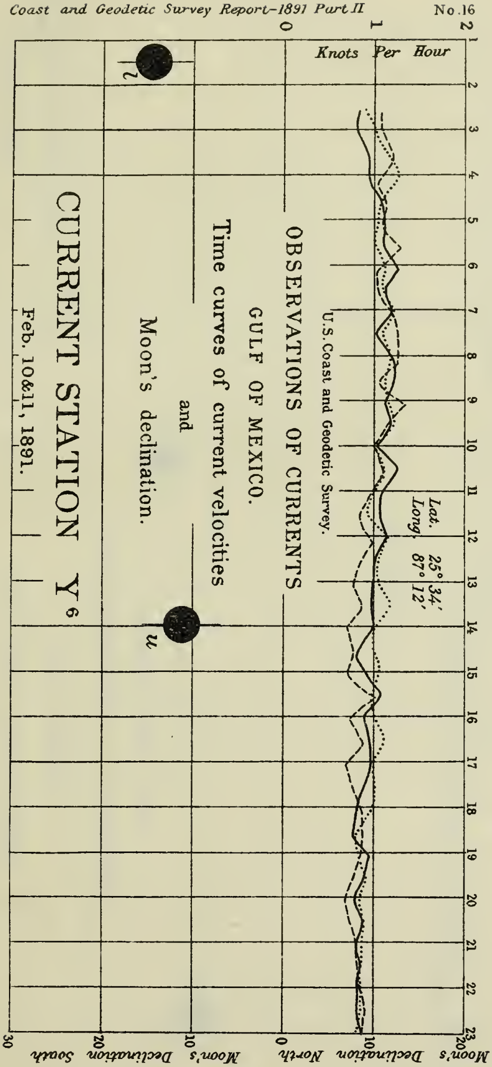
Before closing I wish to call attention to those Physical Maps of the Gulf of Mexico and adjacent waters on which will be seen sweeping lines representing the current issuing from the Caribbean Sea, following close around the Peninsula of Yucatan, the remaining coast of Mexico and the coast of the Gulf States and out the Straits of Florida. The first and the last of this movement, viz, the current through the Yucatan Channel and out the Straits of Florida are well established

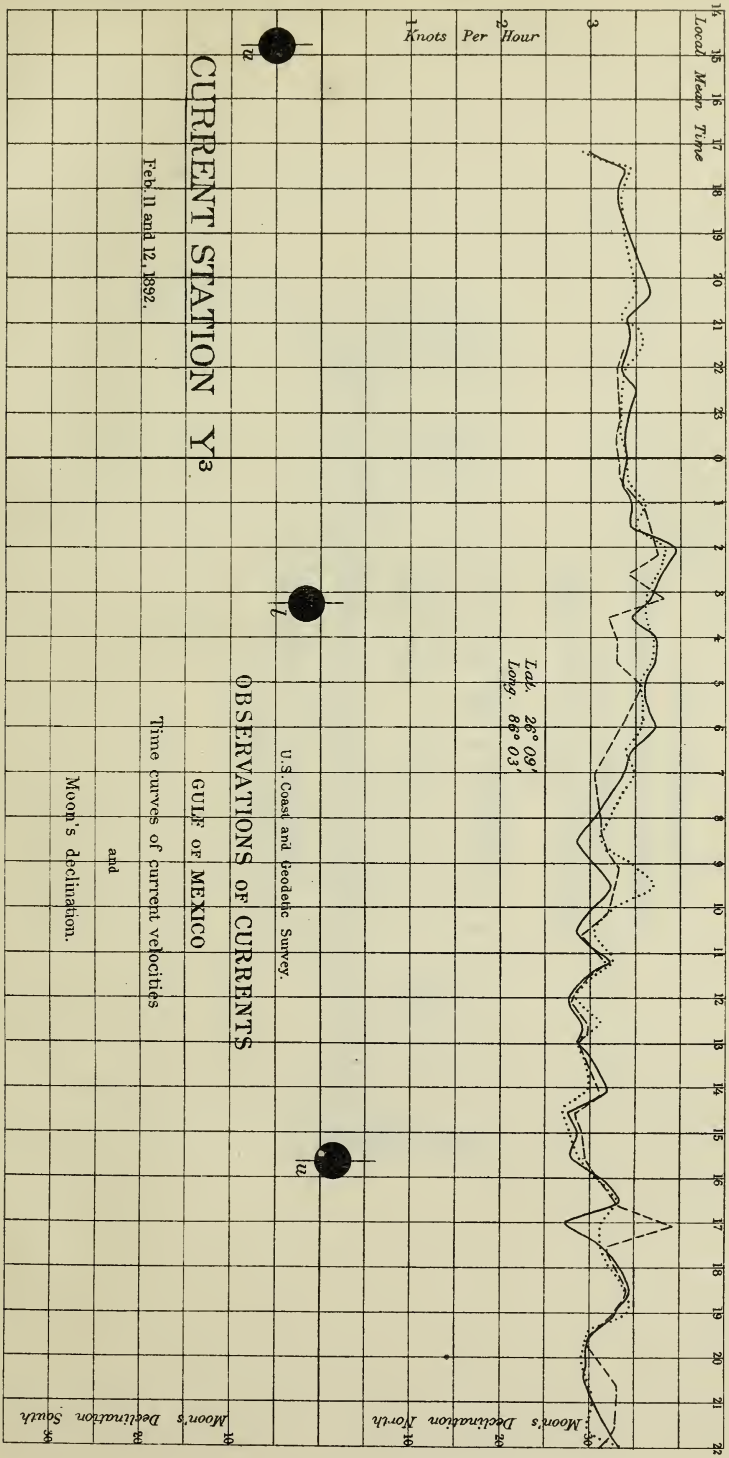
facts. But the remainder is decidedly questionable. In fact, as has been shown, the evidence gathered from our observations is that under normal conditions—and by normal conditions is meant the surface of the Gulf free from stress of either wind or barometric gradient—there is a current running northward along the Florida Banks, sweeping westward past the Mississippi delta and along the Texas coast. As additional evidence of this current it is said that as a rule steamers entering by the Straits of Florida or leaving Havana bound for Pensacola, Mobile, or New Orleans, make landfall to the westward of their course. The *Blake* experienced this on two occasions when running from her working ground to Mobile and Pensacola respectively for coal. Each time on making land we were some few miles to the westward of the entrance to these harbors although some allowance for such a current had been made in the course.

From our present knowledge we cannot say what path the current from the Caribbean Sea takes before passing out of the Straits of Florida and becoming the Gulf Stream. Whether when uninfluenced by atmospheric conditions it follows one regular path that traverses the Gulf or different paths at different phases of the moon, or still further whether at certain phases it has a course parallel with the northern shore of Cuba and at others one traversing the Gulf of Mexico, is an open question. It seems possible however, that the atmospheric conditions over the Gulf of Mexico could be such as to force this stream along the coast of Cuba and out the Straits of Florida without its entering the Gulf at all. And *vice versa* that the atmospheric conditions over the Gulf could be such as to make it a reservoir for this stream, materially diminishing for a time the flow in the Straits of Florida.

In conclusion I wish to express my acknowledgment of the kindness of Lieut. C. E. Vreeland, U. S. Navy, assistant Coast and Geodetic Survey, commanding the *Blake*, in rendering me every assistance possible toward making the trial of the meter a success, and to her officers, Lieut. Harry Kimmell, U. S. Navy; Ensigns R. P. Schwerin, W. C. P. Muir, Jos. H. Rohrbacher, Benjamin Wright, and Philip Andrews, U. S. Navy; Assistant Engineer W. W. White, U. S. Navy; Assistant Surgeon E. S. Bogert, U. S. Navy; and Mr. W. S. Crosby, for kind assistance in carefully taking the observations.


U.S. Coast and Geodetic Survey.
OBSERVATIONS OF CURRENTS
GULF OF MEXICO.
Time curves of current velocities
and
Moon's declination.
CURRENT STATION X4
Feb. 8&9, 1891
Lat. 23° 58'
Long. 87° 09'
Knots Per Hour
Local Mean Time
Moon's Declination North
Moon's Declination South
.... 2 Fathoms
——— 3½ "
- - - - 15 "
-·-·-·30 "
Last Quarter
New Moon
First Quarter
Full Moon
Last Quarter Upper or Lower Transit.
u or l


Knots Per Hour
U.S. Coast and Geodetic Survey.
OBSERVATIONS OF CURRENTS
GULF OF MEXICO.
Time curves of current velocities
and
Moon's declination.
CURRENT STATION Y6
Feb. 10&11, 1891.
Lat. 25° 34'
Long. 87° 12'
Moon's Declination North
Moon's Declination South


CURRENT STATION Y3
Feb. 11 and 12, 1892.
OBSERVATIONS OF CURRENTS
GULF OF MEXICO
U.S. Coast and Geodetic Survey.
Time curves of current velocities
and
Moon's declination.
Lat. 26° 09'
Long. 86° 03'
Knots Per Hour
Local Mean Time
Moon's Declination North
Moon's Declination South

U.S. Coast and Geodetic Survey.

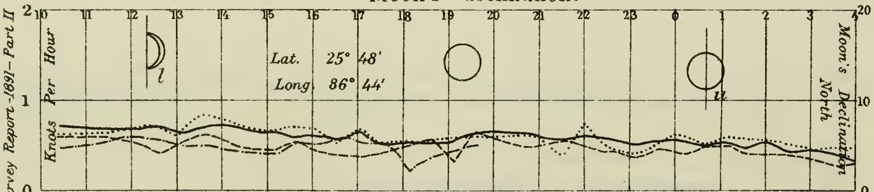
OBSERVATIONS OF CURRENTS

GULF OF MEXICO.

Time curves of current velocities

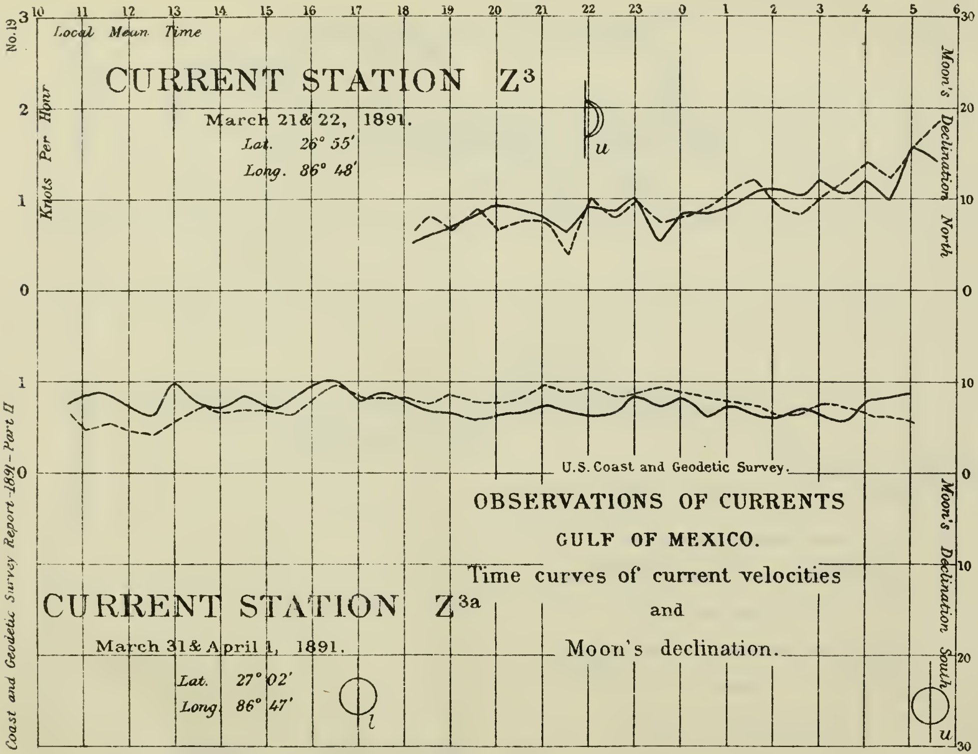
and

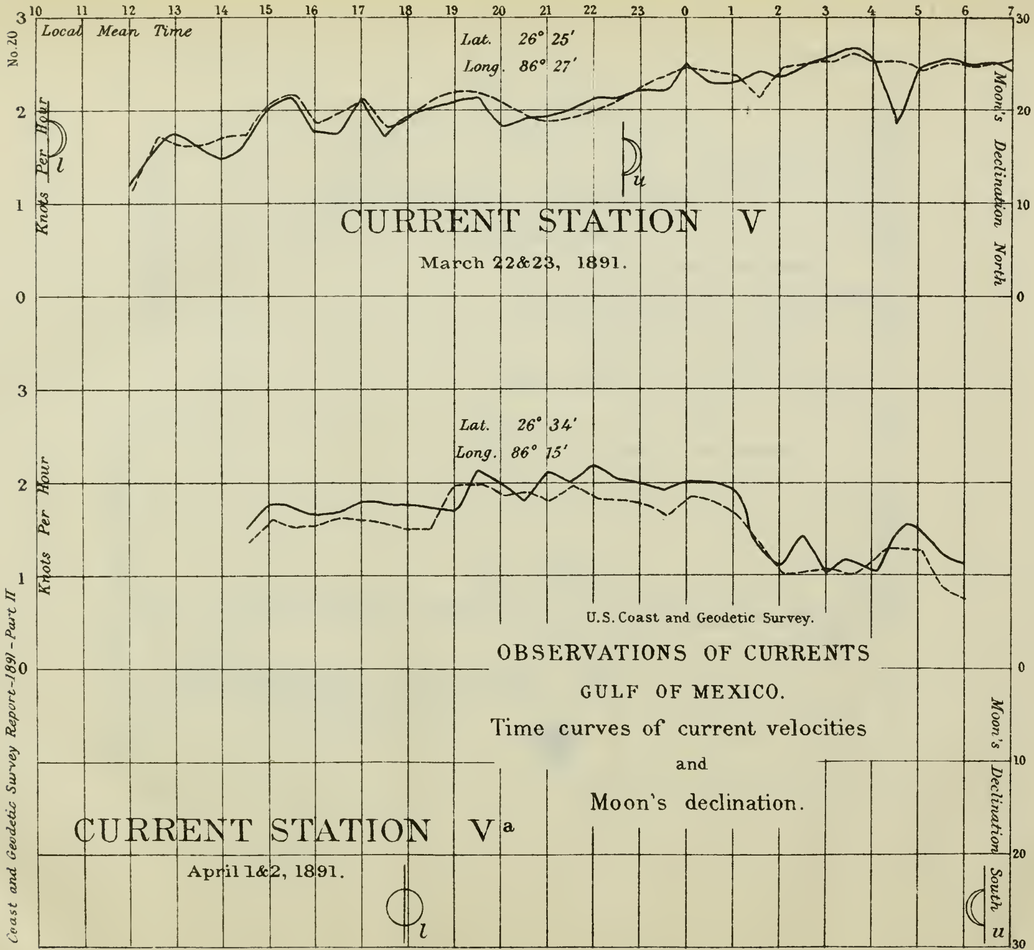
Moon's declination.



CURRENT STATION Y^5

Feb. 23&24, 1891.


Local Mean Time
Knots Per Hour
CURRENT STATION Z3
March 21 & 22, 1891.
Lat. 26° 55'
Long. 86° 48'
u
Moon's Declination North
CURRENT STATION Z3a
March 31 & April 1, 1891.
Lat. 27° 02'
Long. 86° 47'
l
u
Moon's Declination South
U.S. Coast and Geodetic Survey.
OBSERVATIONS OF CURRENTS
GULF OF MEXICO.
Time curves of current velocities
and
Moon's declination.



U.S. Coast and Geodetic Survey.

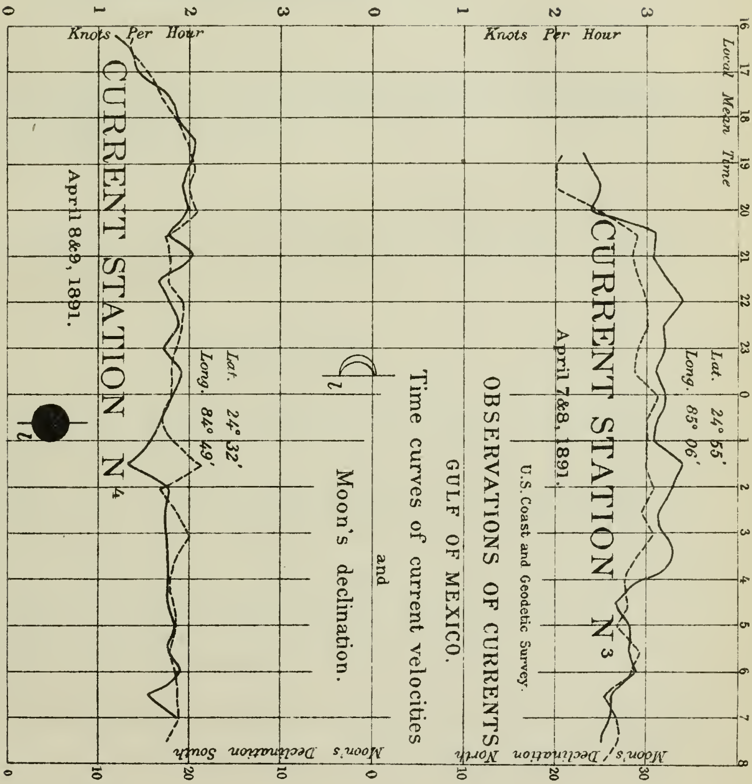
OBSERVATIONS OF CURRENTS

GULF OF MEXICO.

Time curves of current velocities

and

Moon's declination.


OBSERVATIONS OF CURRENTS
GULF OF MEXICO.
Time curves of current velocities
and
Moon's declination.
U.S. Coast and Geodetic Survey.
CURRENT STATION N 3
April 7&8, 1891.
Lat. 24° 55'
Long. 85° 06'
CURRENT STATION N 4
April 8&9, 1891.
Lat. 24° 32'
Long. 84° 49'
Knots Per Hour
Local Mean Time
Moon's Declination North
Moon's Declination South

APPENDIX No. 11—1891.

DESCRIPTIVE CATALOGUE OF PUBLICATIONS RELATING TO THE U. S. COAST AND GEODETIC SURVEY, 1807-1890, AND TO U. S. STANDARD WEIGHTS AND MEASURES, 1790-1890.

Compiled by EDWARD GOODFELLOW, C. H. SINCLAIR, and J. B. BAYLOR, Assistants.

CLASSIFICATION.

I.—Annual Reports and other documents of the U. S. Coast and Geodetic Survey, and U. S. Standard Weights and Measures, 1807 to1890. Also, Reports and other documents relating to U. S. Standard Weights and Measures, 1790-1890.

II.—A Subject-index to the professional papers contained in the Annual Reports, in the Bulletins, and in the occasional publications of the Survey from 1845 to 1890, inclusive.

III.—Bibliography (*a*); statistics (*b*); official reports of expenditures and of persons employed (*c*); tabular statements of information furnished (*d*); Annual Reports of office operations (*e*); and necrology (*f*).

IV.—Tide tables from the date of earliest publication by the Survey to the year 1890.

V.—Coast Pilots from the date of earliest publication by the Survey to the year 1890.

VI.—Catalogues of maps and charts published between 1843 and 1890.

VII.—Notices to mariners.

VIII.—Bulletins.

I.

ANNUAL REPORTS AND OTHER DOCUMENTS OF THE U. S. COAST AND GEODETIC SURVEY, 1807 TO 1890, AND U. S. STANDARD WEIGHTS AND MEASURES, 1790 TO 1890.

U. S. COAST AND GEODETIC SURVEY.

REPORTS AND OTHER DOCUMENTS.

Date.	Subject.	Number of pages and size.
1807. Feb. 10	An act to provide for surveying the coast of the United States*	1, octavo.
Mar. 25	Circular letter addressed by the Secretary of the Treasury to F. R. Hassler, requesting that he would suggest the outlines of a plan for the survey of the coast, such as would unite correctness and practicability. [Transactions American Philosophical Society. Vol. II. New series.]	2, quarto.
Apr. 2	Letter of Mr. Hassler to the Secretary of the Treasury, transmitting a plan for putting into operation the survey of the coast of the United States. [Transactions American Philosophical Society. Vol. II. New series.]	13, quarto.
1808.	Part of volume of Executive reports—Receipts and Expenditures of the United States. Survey of the coast. [Tenth Congress.]	
Dec. 26	Part of estimates of appropriations for support of the Government for 1809. Surveying department. [Tenth Congress, second session.]	
1816. Apr. 4	Report on Coast Survey by the Secretary of the Treasury. Measures taken towards a survey of the coast, etc. [Executive reports, Fourteenth Congress, first session.]	13, quarto.
May 15	Communication made to the Secretary of the Treasury by F. R. Hassler, on the measures necessary to be taken to put into immediate operation such portions of the work as could be undertaken during the coming season.	
	NOTE.—The titles of the reports and other documents relating to the U. S. Coast Survey which follow, and which cover the years between 1816 and 1844, are taken for the most part from two octavo volumes published by Mr. Hassler, and containing in Volume I the "Principal documents relating to the survey of the coast of the United States since 1816 (New York, 1834)" and in Volume II the "Principal documents, etc., from October, 1834, to November, 1835 (New York, 1835)." These two volumes (340 pages, octavo) are bound into a large octavo volume and form part of the "Coast Survey and Weight and Measure Documents, 1832 to 1843." Poore's Descriptive Catalogue of Government Publications, 1774–1881, has also been consulted.	
June 11, 18; July 12; Aug. 3, 18.	Correspondence with the Treasury Department and articles of engagement between the Treasury Department of the United States and F. R. Hassler, relative to the survey of the coast of the United States.	9, octavo.
Nov. 23, 30	First Report of F. R. Hassler, Superintendent of the Survey of the Coast of the United States, to the Secretary of the Treasury upon the progress of the work.	3, octavo,
1818. Mar. 16	Message of President Monroe transmitting a report of the Secretary of the Treasury upon the progress made in the coast surveys. Instructions to the Superintendent, and his report to the Secretary. [State Papers. No. 143, Fifteenth Congress, first session. Vol. II.]	21, octavo.
Apr. 9	Letter of Mr. Hassler to the Secretary of the Treasury, discussing the objects of the survey of the coast and reviewing the progress of the work.	5, octavo.
Apr. 14	An act to repeal part of the act entitled "An act to provide for surveying the coasts of the United States," approved April 14, 1818.	

*The first survey of any considerable extent of the coast of the United States was that of the North Carolina coast between Cape Hatteras and Cape Fear, as appears by letters of Albert Gallatin, Secretary of the Treasury, to the Commissioners appointed for that duty.—[Executive documents, Ninth Congress, first session, April 27, 1806, and second session, January 23, 1807.

U. S. COAST AND GEODETIC SURVEY—Continued.

REPORTS AND OTHER DOCUMENTS—Continued.

Date.	Subject.	Number of pages and size.
1818. Apr. 22	Letter of F. R. Hassler to the Secretary of the Treasury, in regard to the repeal of the act authorizing the survey of the coast and making statement of arrangements desirable for the preservation of the work already accomplished.	2, octavo.
Apr. 27	Communication by Mr. Hassler to the Secretary of War, respecting the transfer of the work of the Coast Survey to the War Department; also, a statement of the "Principal dates of the survey of the coast."	13, octavo.
1820. Nov. 16	Report of the Secretary of the Treasury of the money annually appropriated and paid since 1775 for surveying the seacoast, bays, inlets, harbors, and shoals, etc. [Senate Doc. No. 6, Sixteenth Congress, second session. Vol. I.]	11, octavo.
1828. May 1	Documents relative to coast surveys. Statements relative to the survey of the coasts of the United States. Surveys made, and by whom. [House Ex. Doc. No. 264, Twentieth Congress, first session. Vol. VI.]	11, octavo.
1831. Dec. 22	Documents referring to Coast Survey. Statements relative to the expediency of providing for the completion of the survey of the coasts of the United States. [House Ex. Doc. No. 22, Twenty-second Congress, first session. Vol. II.]	11, octavo.
July 10	An act to carry into effect the act to provide for a survey of the coast of the United States. Approved July 10, 1832.	
July	Letter of F. R. Hassler to the Secretary of the Treasury, presenting the principles and views of his plan of operation for the survey of the coast as adopted in 1807.	9, octavo.
Aug. 6	Upon the articles of agreement between the Treasury Department of the United States and F. R. Hassler, relative to the survey of the coast of the United States.	2, octavo.
Aug. 9	Letter of the Secretary of the Treasury to F. R. Hassler, appointing him to make, under the direction of the Treasury Department, the survey of the coast as provided for by the acts of February 10, 1807, and July 10, 1832.	1, octavo.
Aug. 9	Circular letter from the Secretary of the Treasury, requesting all owners and occupiers of lands over which Mr. Hassler and his assistants may have occasion to pass in the performance of their public duties to permit them freely to pass over and remain on the same as long as may be necessary in executing the work of the survey of the coast.	
1833. Dec. 1	Letter of Mr. Hassler to the Secretary of the Treasury, reporting the progress made in the work of the survey of the coast.	2, octavo.
1834. Mar. 12	Letter from the Secretary of the Treasury to Mr. Hassler, informing him that, with the approval of the President, the superintendence of the Coast Survey has been transferred from the Treasury to the Navy Department.	
Mar. 14 to Apr. 14.	Correspondence of Mr. Hassler with the Secretary of the Navy, relative to the transfer of the Coast Survey to the Navy Department, with a "Continuation of the principal facts and dates relating to the Coast Survey, after the interruption of the work in 1818."	19, octavo
May 17	Report by F. R. Hassler to the Secretary of the Navy upon the "Works executed for the survey of the coast of the United States, upon the law of 1832, and their junction with the works made in 1817 by and under the direction of F. R. Hassler."	14, octavo.
Nov. 11	Report of F. R. Hassler as Superintendent of the Survey of the Coast, additional to that dated May 17, containing an account of the progress of that work during the summer and until November of 1834.	7, octavo.
1835. Feb. 17	Statement by F. R. Hassler of the "Considerations which make an increase of the appropriation proposed for the survey of the coast for the present year desirable and advantageous."	2, octavo.
May 8	Third report of F. R. Hassler, as Superintendent of the Survey of the Coast, upon the progress of that work from November, 1834, to May, 1835.	4, octavo.

U. S. COAST AND GEODETIC SURVEY—Continued.

REPORTS AND OTHER DOCUMENTS—Continued.

Date.	Subject.	Number of pages and size.
1832. Nov. 22	Fourth report of F. R. Hassler, as Superintendent of the Survey of the Coast, upon the operations performed in that work between the months of May and December, 1835, with an estimate of the appropriation required for the next year's work.	6, octavo.
1836. Mar. 8	Statement made by Mr. Hassler to the Secretary of the Navy of reasons for placing the Coast Survey in the Treasury Department, and neither in the War nor Navy Departments.	2, octavo.
Mar. 25-27 ..	The direction of the Coast Survey transferred from the Navy Department to the Treasury Department. See letters of March 25 from the Secretary of the Navy to Mr. Hassler, and of March 27 from Mr. Hassler to the Secretary of the Treasury.	15, octavo.
Apr. 13, 18, 30	Reports from the Secretary of the Treasury and the Chief of the Topographical Bureau, U. S. Army, upon the salaries of the Superintendent of the Coast Survey and his assistants, with remarks by Mr. Hassler in relation thereto.	15, octavo.
Nov. 19	Fifth report of F. R. Hassler, as Superintendent of the Coast Survey, * * * exhibiting the operations performed in 1836.	5, octavo.
Dec. 7.......	Report on the Coast Survey by the Secretary of the Treasury. Statement relative to the transfer of the Coast Survey from the Navy Department to the Treasury, with copies of correspondence relating to the subject, and the report of F. R. Hassler, Superintendent of the Survey. [Ex. Doc. No. 13, Twenty-fourth Congress, second session, Vol. I.]	60, octavo.

UNITED STATES COAST AND GEODETIC SURVEY AND U. S. STANDARD WEIGHTS AND MEASURES.

ANNUAL REPORTS.

FERDINAND RUDOLPH HASSLER, *Superintendent.*

Period of report.	Subject.	Number of pages and size.	Designation as a public document.
1837............	United States Coast Survey	5, octavo	Twenty-fifth Congress, second session, No. 79, Senate.
	Weights and Measures	11, octavo	Do.
1838............	United States Coast Survey	6, octavo	Twenty-fifth Congress, third session, No. 4, Senate.
	Weights and Measures	1, octavo	Do.
1839............	United States Coast Survey	6, octavo	Twenty-sixth Congress, first session, No. 15, Senate.
	Weights and Measures	2, octavo	Do.
1840............	United States Coast Survey	7, octavo	Twenty-sixth Congress, second session, No. 14, House of Representatives—Treasury Department.
	Weights and Measures	1, octavo	Do.
Dec., 1841	....	18, octavo	Twenty-seventh Congress, second session, No. 28, House of Representatives—Treasury Department.
Jan., 1842*	....	8, octavo	Twenty-seventh Congress, second session, No 57, House of Representatives—Treasury Department.
Dec., 1842*	....	5, octavo	Twenty-seventh Congress, third session, No. 11, Senate.
Jan., 1843 †	....	103, octavo	Twenty-seventh Congress, third session, No. 43, House of Representatives.
Feb., 1843 †	....	93, octavo	Twenty-seventh Congress, third session, No. 170, House of Representatives.
Nov., 1843, ‡ and Jan., 1844.	....	8, octavo	Twenty-eighth Congress, first session, No. 97, House of Representatives—Treasury Department.

* Report in regard to progress and expenditures.
† Reports of select committee of the House of Representatives upon progress and expenditure in the Coast Survey.
‡ Last report of F. R. Hassler, as Superintendent of the Coast Survey, transmitted January 29, 1844, by the Secretary of the Treasury to Congress.

U. S. COAST AND GEODETIC SURVEY—Continued.

ANNUAL REPORTS.

ALEXANDER DALLAS BACHE, *Superintendent.*

Report for year ending—	Number of pages and size.	Number of appendices.	Number of illustrations.	Designation as a public document.
Nov., 1844	22, octavo	....	4	Twenty-eighth Congress, second session, No. 25, House of Representatives—Treasury Department.
1845	44, octavo	4	3	Twenty-ninth Congress, first session, No. 38, House of Representatives—Treasury Department.
1846	74, octavo	11	9	Twenty-ninth Congress, second session, No. 6, House of Representatives—Treasury Department.
Oct., 1847	88, octavo	18	11	Thirtieth Congress, first session, Senate Ex. No. 6.
Nov., 1848	120, octavo	19	16	Thirtieth Congress, second session, Senate Ex. No. 1.
1849	98, octavo	20	16	Thirty-first Congress, first session, Senate Ex. No. 5.
1850	134, octavo	37	27	Thirty-first Congress, second session, House Ex. Doc. No. 12.
1851	559, octavo	57	....	Thirty-second Congress, first session, Senate Ex. Doc. No. 3.
1851	quarto	....	58	One volume, quarto, sketches accompanying the Annual Report of the Superintendent U. S. Coast Survey for 1851.
1852*	173, quarto	52	37	Thirty-second Congress, second session, House Ex., No. 64.
Oct., 1853	186, quarto	58	54	Thirty-third Congress, first session, Senate Ex., No. 14.
1854	288, quarto	73	58	Thirty-third Congress, second session, House Ex. Doc. No. 20.
1855	420, quarto	86	60	Thirty-fourth Congress, first session, House Ex. Doc. No. 6.
1856	358, quarto	86	67	Thirty-fourth Congress, third session, Senate Ex. Doc. No. 12.
1857	448, quarto	65	72	Thirty-fifth Congress, first session, Senate Ex. Doc. No. 33.
1858	464, quarto	50	40	Thirty-fifth Congress, second session, Senate Ex. Doc. No. 14.
1859	371, quarto	43	40	Thirty-sixth Congress, first session, House Ex. Doc. No. 41.
1860	409, quarto	45	30	Thirty-sixth Congress, second session, Senate Ex. Doc.
1861	270, quarto	34	31	Thirty-seventh Congress, second session, Senate Ex. Doc.
1862	434, quarto	40	41	Thirty-seventh Congress, third session, House Ex. Doc. No. 70.
1863	218, quarto	29	30	Thirty-eighth Congress, first session, Senate Ex. Doc.
1864	315, quarto	24	39	Thirty-eighth Congress, second session, Senate.

* Beginning with 1852, the reports of the Superintendent for each year appear in one volume, quarto.

JULIUS ERASMUS HILGARD, *Acting Superintendent.*

Oct., 1865	231, quarto	22	32	Thirty-ninth Congress, first session, House Ex. Doc. No. 75.
1866	140, quarto	20	30	Thirty-ninth Congress, Second session, House Ex. Doc. No. 87.

BENJAMIN PEIRCE, *Superintendent.*

Oct., 1867	334, quarto	20	28	Fortieth Congress, second session, House Ex. Doc. No. 275.
1868	277, quarto	15	29	Fortieth Congress, third session, House Ex. Doc. No. 71.
1869	259, quarto	15	28	Forty-first Congress, second session, House Ex. Doc. No. 206.
1870	232, quarto	22	28	Forty-first Congress, third session, House Ex. Doc. No. 112.
1871	219, quarto	18	36	Forty-second Congress, second session, House Ex. Doc. No. 121.
1872	267, quarto	18	24	Forty-second Congress, third session, House Ex. Doc. No. 240.
1873	180, quarto	15	18	Forty-third Congress, first session, House Ex. Doc. No. 133.

U. S. COAST AND GEODETIC SURVEY—Continued.

ANNUAL REPORTS—Continued.

CARLILE POLLOCK PATTERSON, *Superintendent.*

Report for year ending—	Number of pages and size.	Number of appendices.	Number of illustrations.	Designation as a public document.
June, 1874	242, quarto	18	24	Forty-third Congress, second session, House Ex. Doc. No. 100.
1875	412, quarto	20	37	Forty-fourth Congress, first session, House Ex. Doc. No. 81.
1876	416, quarto	23	37	Forty-fourth Congress, second session, Senate Ex. Doc. No. 37.
1877	192, quarto	15	25	Forty-fifth Congress, second session, Senate Ex. Doc. No. 12.
1878	304, quarto	11	39	Forty-fifth Congress, third session, Senate Ex. Doc. No. 13.
1879	213, quarto	16	53	Forty-sixth Congress, second session, Senate Ex. Doc. No. 17.
1880	419, quarto	19	84	Forty-sixth Congress, third session, Senate Ex. Doc. No. 12.

JULIUS ERASMUS HILGARD, *Superintendent.*

June, 1881	471, quarto	18	63	Forty-seventh Congress, first session, Senate Ex. Doc. No. 49.
1882	565, quarto	24	52	Forty-seventh Congress, second session, Senate Ex. Doc. No. 77.
1883	488, quarto	19	50	Forty-eighth Congress, first session, Senate Ex. Doc. No. 29.
1884	622, quarto	19	25	Forty-eighth Congress, second session, House Ex. Doc. No. 43.

NOTE.—Abstracts of the reports for 1882, 1883, and 1884 were prepared for early distribution and published as Treasury Department documents 364, 541, and 652 Coast and Geodetic Survey, each abstract containing about 20 pages octavo.

FRANK M. THORN, *Superintendent.*

June, 1885	516, quarto	18	46	Forty-ninth Congress, first session, House Ex. Doc. No. 18.
1886	435, quarto	13	39	Forty-ninth Congress, second session, House Ex. Doc. No. 40.
1887	514, quarto	16	49	Fiftieth Congress, first session, House Ex. Doc. No. 17.
1888	566, quarto	14	60	Fiftieth Congress, second session, House Ex. Doc. No. 22.

THOMAS CORWIN MENDENHALL, *Superintendent.*

June, 1889	503, quarto	18	50	Fifty-first Congress, first session, House Ex. Doc. No. 55.
1890	780, quarto	20	71	Fifty-first Congress, second session, House Ex. Doc. No. 80.

NOTE.—For other papers and documents relating to the U. S. Coast and Geodetic Survey, printed or published from the year 1844 until the year 1890, see Bibliography.

UNITED STATES STANDARD WEIGHTS AND MEASURES.

REPORTS AND OTHER DOCUMENTS.

1790 to 1890.

Date.	Subject.	Number of pages and size.
	NOTE.—The titles which are here given of papers having an official character or a historical interest relating to U. S. Standard Weights and Measures, and which were printed or published between 1790 and 1830, have been taken (with some slight changes) from Poore's Descriptive Catalogue of Government Publications of the United States, 1774 to 1881.	
1790. Jan. 8	Annual message to Congress. President Washington [First Congress, second session.] The President urges the importance of uniformity in the currency, weights, and measures of the United States.	
July 4	Report on Weights, Measures, and Coinage—By Thomas Jefferson, Secretary of State. [Ex. Docs., First Congress, second session.] On the subject of establishing a uniformity in the weights, measures, and coins; consideration upon the use of the pendulum as a measure of determinate length; recommends that the standard of measure be an uniform cylindrical rod of iron of such length that it shall perform its vibrations in small and equal arcs in one second of mean time; weights and measures in use in Great Britain; reports of committees of the House of Commons in 1757–'59; examination of the system of measures in use in the United States; standard for coins; recommendations for changes in the weights and measures in the United States; the measures, weights, and coins of the decimal system, estimated in those of England, now used in the United States.	
1791. Oct. 5	Annual message to Congress [Second Congress, first session.] President Washington calls attention to the necessity of action upon the subject of uniformity in currency, weights, and measures.	
1792. Apr. 5	Report of the Committee on Weights and Measures—R. Izard, Senator [Journal of the Senate, Second Congress, first session, pp. 173, 174.] Fixing a standard for weights and measures; directions for the scientific construction of a standard rod; division of the rod into five equal parts, one of which shall be called a foot; measures in the survey of lands; units of weight.	2.
1795. Jan. 9	Communication from Minister of French Republic [Ex. Docs., Third Congress, second session.] Regarding the adoption by the United States of a system of weights and measures conformable to that lately adopted by France; detailed description of the new method; standards of mensuration; standard of weight; division of the standards into decimal parts.	
1796. Apr. 12	Reports on Weights and Measures—Representative Carter B. Harrison [Ex. Docs., Fourth Congress, first session.] Regulations of the standard of weights and measures; divisions of the pound; divisions of the ounce; scientific experiments to be made by scientists to be employed by the Government to fix upon a standard of weights and measures.	7.
1819. Jan. 25	Report on a standard of weights and measures—Select committee of Congress. [House Docs. No. 109, Fifteenth Congress, second session. Vol. VI.] Recommends that models of the yard, bushel, and pound, conforming to those in most common use, be made under the direction of a Commission to be selected by the President, and which, if satisfactory to Congress, shall be declared the standard weights and measures of the United States.	12.
1821. Feb. 22	Report on Weights and Measures—By John Quincy Adams, Secretary of State. [Ex. Papers, No. 109, Sixteenth Congress, second session. Vol. VIII.] Plan of a standard of weights and measures to be adopted by the United States, prepared in conformity with a resolution of the House of Representatives, dated December 14, 1819.	245.
1822. Mar. 11	Report on Weights and Measures. Select committee [Reports of committees, No. 65, Seventeenth Congress, first session. Vol. I.] The President of the United States should be requested to obtain for the use of the different States and Territories duplicates of the English measures weights, etc.	4.

UNITED STATES STANDARD WEIGHTS AND MEASURES—Continued.

REPORTS AND OTHER DOCUMENTS—Continued.

Date.	Subject.	Number of pages and size.
1830. May 29	Extract from Senate Journal: On motion of Mr. Woodbury, and by unanimous consent, *Resolved*, That the Secretary of the Treasury be directed to cause a comparison to be made of the standards of weights and measures now used at the principal custom-houses in the United States, and report to the Senate at the next session of Congress. NOTE.—The titles which follow of the reports and other documents relating to United States weights and measures have been taken chiefly from copies of the documents themselves on file in the libraries of the Coast and Geodetic Survey and the Office of Standard Weights and Measures. The greater part of them are found in three bound volumes, octavo, viz: Coast Survey and Weight and Measure Documents, 1832 to 1843; Congressional and Departmental Documents, Vol. I, 1830-1856, Vol. II, 1857-1889.	
1831. Mar. 3	Report on Weights and Measures—By S. D. Ingham, Secretary of the Treasury. [Senate Docs., No. 74, Twenty-first Congress, second session. Vol. II.] Relative to comparison of weights and measures used in custom-houses.	2, octavo.
Apr. 30, June 18.	Letters of the Secretary of the Treasury to F. R. Hassler, Superintendent United States Standard Weights and Measures, respecting permanent standards of weights and measures for the Treasury Department; the manufacture of weights and measures for all the custom-houses in the United States, and the adoption of units of weight and of capacity.	2, octavo.
1832. Mar. 5	An enumeration by Mr. Hassler of the objects and statements desirable to form a collection of standard weights and measures of foreign countries for the Department of State of the United States.	3, octavo.
June 20	Report of the Secretary of the Treasury, in compliance with a resolution of the Senate, showing the result of an examination of the weights and measures used in the several custom-houses in the United States. [Twenty-second Congress, first session, Doc. No. 299, House of Representatives.]	122, octavo.
1834. July and Aug., and Jan. and Feb., 1835.	Correspondence with the Secretary of the Treasury, and reports of progress in the construction of standard weights and measures. F. R. Hassler, Superintendent.*	20, octavo.
1835. Feb. 27	Mr. Binney, from select committee to which the subject had been referred, made the following report on a memorial from citizens of Philadelphia, praying Congress to establish a standard of weights and measures throughout the Union, and uniform mode of applying and conforming to the same. [Twenty-third Congress, second session, Report No. 132, House of Representatives.]	31, octavo.
Dec. 26	Letter from the Secretary of the Treasury, transmitting information in relation to a standard of weights and measures. [Twenty-fourth Congress, first session, Doc. No. 32, House of Representatives—Treasury Department.]	7, octavo.
1836. Jan. 30	Report of the Committee on Commerce in relation to the expediency of furnishing the States and Territories with the standard weights and measures selected and adopted by the Executive, to be used in the collection of the revenue of the United States. [Twenty-fourth Congress, first session, Report No. 259, House of Representatives.]	2, octavo.
Mar. 21	Mr. Pinckney, from the Committee on Commerce, submitted a report on a resolution directing them to inquire into the expediency of providing for the distribution among the States and Territories of the same standards of weights and measures which have been ordered to be provided for the custom-houses. [Twenty-fourth Congress, first session, Report No. 449, House of Representatives.] NOTE.—This is a report substantially the same in effect as the one of January 30, 1836, and recommends the adoption of the same resolution.	2, octavo.

*Contained in volume with following title: Documents relating to the construction of uniform standards of weights and measures for the United States, from 1832 to 1835. Published by F. R. Hassler, superintendent of the work. New York: Printed by John Windt, 1836.

UNITED STATES STANDARD WEIGHTS AND MEASURES—Continued.

REPORTS AND OTHER DOCUMENTS—Continued.

Date.	Subject.	Number of pages and size.
1836. Apr. 30, and May 13, 18.	Correspondence with the Secretary of the Treasury in relation to a comparison of the Troy pound sent from England with the Troy pound of the United States Mint, and relative to the construction of standard weights for the United States Mint at Philadelphia.	5, octavo.
June 16	Letter of the Secretary of the Treasury to F. R. Hassler, Superintendent of Weights and Measures, inclosing copy of a joint resolution of Congress in regard to the preparation of complete sets of standard weights and measures for each of the States of the Union.	8, octavo.
June 17	Reply of Mr. Hassler to the Secretary	2, octavo.
July 28 and Aug. 10.	Letters of Mr. Hassler to the Secretary relating to the completion and delivery of six sets of standard weights, one set to the Treasury Department and five sets for custom-houses.	2, octavo.
Nov. 19	Report of progress in the construction of standard weights and measures, by F. R. Hassler, Superintendent. [This report is combined with that of the Coast Survey.]	2, octavo.
1837. Nov. 18	Report by F. R. Hassler, Superintendent Weights and Measures, upon the establishment of the system of ounce weights for the mints of the United States. [Above forms part of Senate Doc. No. 79 and of House Doc. No. 20, Twenty-fifth Congress, second session.]	10, octavo.
1838. July 3	Letter from the Secretary of the Treasury, transmitting a report of F. R. Hassler, stating that complete sets of standard weights and measures for the respective States of the Union have been prepared and are now ready for delivery. [House Doc. No. 454, Twenty-fifth Congress, second session—Treasury Department.]	
June 26	Report to the Treasury Department of the United States upon the construction and completion of the standards of weight for all the States of the Union. [House Doc. 454, Twenty-fifth Congress, second session.]	6, octavo.
Nov. 14	Seventh report of F. R. Hassler, as superintendent of the construction of standards of weights and measures. [Part of Senate Doc. No. 4, Twenty-fifth Congress, third session.]	1, octavo.
1839. Nov. 16	Upon the construction of the standards of weights and measures [Part of Senate Doc. No. 15 and of House Doc. No. 20, Twenty-sixth Congress, first session.]	2, octavo.
1840. July 10	Report upon the completion of the standard yard measures for the respective States—by F. R. Hassler, Superintendent of Weights and Measures. [House Doc. No. 261, Twenty-sixth Congress, first session.]	6, octavo.
Nov. 17	Upon the construction of standard weights and measures [Part of House Doc. No. 14, Twenty-sixth Congress, second session.]	1, octavo.
1841. June 22	Report upon the completion of the standard ounce weights for all the States of the Union—by F. R. Hassler, Superintendent of Weights and Measures. [House Doc. No. 33, Twenty-seventh Congress, first session.]	4, octavo.
1842. Apr. 5	Report upon the construction of standards of liquid capacity measures, with descriptions of the apparatus devised for standarding, tables of last weighings, and ultimate results of adjustment. With 3 illustrations. [Senate Doc. No. 225 and House Doc. No. 176, Twenty-seventh Congress, second session.]	26, octavo.
June 29	Report by F. R. Hassler upon the works of the establishment of uniform weights and measures for the United States, made upon a call from the select committee of the House of Representatives.	17, octavo.
Dec. 19	Letter from the Secretary of the Treasury transmitting a report of Prof. Hassler, Superintendent of the Coast Survey, the last paragraphs of which relate to weights and measures. [House Doc. No. 23 and Senate No. 11, Twenty-seventh Congress, third session—Treasury Department.]	

UNITED STATES STANDARD WEIGHTS AND MEASURES—Continued.

REPORTS AND OTHER DOCUMENTS—Continued.

Date.	Subject.	Number of pages and size.
1843. Mar. 2	Committee on Commerce (Mr. Randall), to whom was referred the petition of William Nixon, reports adversely to the adoption of the metric system of weights and measures. [House Report No. 285, Twenty-seventh Congress, third session.]	
Apr., June, and Nov., and Jan. 31, 1884.	Reports of F. R. Hassler, as superintendent of the construction of standards of weight and measure, upon the progress of the works in the construction of standards since December, 1842. [House Doc. No. 94, Twenty-eighth Congress, first session.] Report transmitted to Congress by the Secretary of the Treasury after the death of Mr. Hassler, together with a tabular statement of the work executed for the system of uniform standards for the United States from the beginning of the year 1836 to June, 1842, with their state at that epoch, and the additions made until November, 1843. Six illustrations.	
1845. Feb. 26, 27	Report of Alexander Dallas Bache, Superintendent, on the construction of standard weights, measures, and balances for the year 1844. [Senate Doc. No. 149 and House Doc. No. 159, Twenty-eighth Congress, second session.]	32, octavo.
1846. Apr. 25 and Aug. 7.	Report upon the progress made in the construction of standard weights, measures, and balances in the year 1845, under the superintendence of A. D. Bache. [Senate Doc. No. 483, Twenty-ninth Congress, first session.]	23, octavo.
1848. July 30 and Aug. 12.	Report to the Treasury Department, by A. D. Bache, on the progress of the work of constructing standards of weights and measures, and balances, in the years 1846 and 1847. Four illustrations. [Senate Ex. Doc. No. 73 and House Ex. Doc. No. 84, Thirtieth Congress, first session.]	29, octavo.
Dec. 12	Reports from the Secretary of the Treasury of scientific investigations in relation to sugar and hydrometers, made under the superintendence of A. D. Bache, by Prof. R. S. McCulloch. Revised edition by order of the Senate. [Senate Ex. Doc. No. 50, Thirtieth Congress, first session.]	
1851. Feb. 7, 10	Letter from A. D. Bache, Superintendent of Weights and Measures, communicating a report of the computation of a manual of tables to be used with the hydrometers recently adopted in the United States custom-houses. With six illustrations. [Senate Ex. Doc. No. 28, Thirty-first Congress, second session.]	168, octavo.
1856. Dec. 31	Report to the Treasury Department of progress made under the superintendence of Alexander D. Bache, in the construction and distribution of standards of weights and measures, and supply of hydrometers to custom-houses; also of balances made and distributed to the States, and the laws severally enacted therein relative to standard weights and measures from the 1st of January, 1848, to the 31st of December, 1856. Six illustrations. [Senate Ex. Doc. No. 27, Thirty-fourth Congress, third session.]	218, octavo.
1858 Dec. 15	Report of the Secretary of the Treasury communicating, in answer to a resolution of the Senate, a report showing the amount expended and the progress made in the Coast Survey, and also (pp. 222–287) the weights and measures furnished the several States and custom-houses and their cost. [Senate Ex. Doc. No. 6, Thirty-fifth Congress, second session.]	
1866 May 17	Mr. Kasson, from the Committee on Coinage, Weights, and Measures, made the following report upon the general subject of a uniform system of coinage, weights, and measures, accompanied by bills and resolutions which, as acts of Congress, were approved July 28, 1866. [House Report No. 62, Thirty-ninth Congress, first session.]	
1867 Mar. 7	Letter of the Vice-president of the National Academy of Sciences communicating, in obedience to law, a report of the proceedings of the Academy during the year 1866. Report on hydrometers, densities, and Manual for Inspectors of Spirits, etc. [Senate Mis. Doc. No. 44, Fortieth Congress, first session.]	
1869 Nov. 15	Report by Benjamin Peirce, Superintendent of Standard Weights and Measures, to the Secretary of the Treasury, upon the progress made in the construction of metric standards of length, weight, and capacity, in pursuance of a joint resolution of Congress of July 27, 1866.	4, octavo.

UNITED STATES STANDARD WEIGHTS AND MEASURES—Continued.

REPORTS AND OTHER DOCUMENTS—Continued.

Date.	Subject.	Number of pages and size.
1871 Nov. 30	Report of an examination of weights and balances at the branch mint, United States, San Francisco, Cal.—By George Davidson, Assistant, U. S. Coast Survey.	
1875 Aug. 17	Memorial to Congress in favor of an International Bureau of weights and measures. Signed by F A. P. Barnard, chairman committee; J. E. Hilgard, H. A. Newton, J. L. Smith, Joseph Henry, W. B. Rogers, Benj. Peirce, E. B. Elliott.	
1876 Mar.	Report on the proposed International Bureau of weights and measures at Paris. Giving a concise history of what has been done by the International Conference—by J. E. Hilgard, Assistant, U. S. Coast Survey, and delegate from the United States to the International Commission.	
Mar. 1	Papers relating to metric standards distributed to the States of the Union under a joint resolution of Congress of July 27, 1866, including a description of the metric standards, with directions for their use—by J. E. Hilgard, Inspector U. S. Standard Weights and Measures.	6, octavo.
	The relation of the lawful standards of measure of the United States to those of Great Britain and France—J. E. Hilgard. [Published as Appendix No. 22 to U. S. Coast Survey Report for 1876.]	5, quarto.
1887	Comparison of American and British standard yards.—J. E. Hilgard. [Published as Appendix No. 12 to U. S. Coast Survey Report for 1877.]	33, quarto.
1878 Mar. 21, 23, 28	Letters of C. P. Patterson, Superintendent Coast Survey, and of J. E. Hilgard, Assistant Coast Survey and Inspector U. S. Standard Weights and Measures, in relation to the proposition for making the use of the metrical system of weights and measures obligatory in all governmental and individual transactions, embodied, with other statements, in a communication from the Secretary of the Treasury, in response to a resolution of the House of Representatives.	7, octavo.
	[House Ex. Doc. No. 71, Forty-fifth Congress, second session.]	37, octavo.
May 8, 18	Statement of J. E. Hilgard, Inspector U. S. Weights and Measures, before the Committee on Coinage, Weights, and Measures, of the House of Representatives, concerning the standard weights and measures of the United States. [House Mis. Doc. No. 61, Forty-fifth Congress, second session.]	12, octavo.
June 11	International Bureau of Weights and Measures. Message from the President of the United States transmitting a communication from the Secretary of State in response to a resolution of the House of Representatives, in relation to the convention for establishing an International Bureau of Weights and Measures. [House Ex. Doc. No. 96, Forty-fifth Congress, second session.]	
1880 Feb. 12	Report by Mr. Stephens, Committee on Coinage, Weights, and Measures, on the metric system of coinage. [House Report No. 203, Forty-sixth Congress, second session.]	
Mar. 5	Report of Mr. Vance, of Committee on Coinage, Weights, and Measures, on a decimal system of weights and measures for the English-speaking nations. [House Mis. Doc. No. 29, Forty-sixth Congress, second session.]	
1881. Mar. 3	Complete set of standard weights and measures to be furnished for the use of the agricultural colleges. Approved March 3, 1881. [Public resolution No. 23.] Joint resolution, directing the Secretary of the Treasury to cause a complete set of all the weights and measures adopted as standards to be delivered to the Governor of each State in the Union for the use of agricultural colleges, etc.	
1886. Jan. 29	Letter from the Secretary of the Treasury transmitting letter from the Superintendent of the Coast and Geodetic Survey, relative to supplying balances, weights, and measures to Territories, etc. [Senate Ex. Doc. No. 55, Forty-ninth Congress, first session.]	
1888. Apr. 26	Letter from the Secretary of the Treasury transmitting an estimate from the Secretary of State of an appropriation to supply deficit for the International Bureau of Weights and Measures. [House Ex. Doc. No. 283, Fiftieth Congress, first session.]	

UNITED STATES STANDARD WEIGHTS AND MEASURES—Continued.

REPORTS AND OTHER DOCUMENTS—Continued.

Date.	Subject.	Number of pages and size.
1889. June 15	Bulletin No. 9.—On the Relation of the Yard to the Metre. By O. H. Tittmann, Assistant.	6, quarto.
....	Appendix No. 6.—Annual Report of the U. S. Coast and Geodetic Survey, 1889. The relation between the metric standards of length of the U. S. Coast and Geodetic Survey and the U. S. Lake Survey.	19, quarto.
Sept. 16	Letter to the Secretary of State transmitting a report upon the subject of weights and measures for the information of the United States delegates to the International American Congress—by T. C. Mendenhall, Superintendent U. S. Coast and Geodetic Survey, and of Weights and Measures.	7, large octavo.
Nov. 30	Verification of Weights and Measures—by O. H. Tittmann, Assistant. (One plate.) [Coast and Geodetic Survey Bulletin, No. 15, 1889.]	2.
1890. Jan. 15	International American Conference. Report of the Committee on Weights and Measures, as adopted by the Conference.	7, large octavo.
January	U. S. Coast and Geodetic Survey. Office of Standard Weights and Measures. T. C. Mendenhall, Superintendant. Tables for converting United States weights and measures, metric and customary.	2, quarto.
....	Appendix No. 16.—1890. On the relation of the yard to the metre.. ..... [Republication, with additions, by Assistant O. H. Tittmann, of his paper first published as Bulletin No. 15.]	6, quarto.
Feb. 18......	Table for the reduction of hydrometer observations of salt-water densities. Prepared for publication by O. H. Tittmann, Assistant. [Coast and Geodetic Survey Bulletin, No. 18, 1890.]	3, quarto,
May 6	Appendix No. 18.—1890. Historical account of United States standards of weights and measures, customary and metric; of the inception and construction of the National Prototypes of the metre and kilogramme; of their transportation from Paris to Washington; of their official opening and certification, and of their deposit in the Office of Weighis and Measures. (One illustration.) Compiled by O. H. Tittmann, Assistant in charge of the Office of Standard Weights and Measures. Brief account of the weights and measures in customary use in the United States, with the legislation relating thereto; customary length measure; customary standard of weight; capacity measures; weights and measures for agricultural colleges; metric standards; coefficient of expansion of the metre bars; construction of the kilogrammes; report of Dr. B. A. Gould, delegate from the United States to the International Conference of Weights and Measures, held at Paris, September, 1889; prototypes of the standard metre and kilogramme of the Bureau International des Poids et Mesures; report of Assistant George Davidson upon delivering one set of these prototypes to Prof. T. C. Mendenhall, Superintendent U. S. Coast and Geodetic Survey, and of Weights and Measures; certificate of President Benjamin Harrison in relation to the opening of the national prototypes of the metre and kilogramme; report of Assistant O. H. Tittmann, upon the transportation of national prototype metre, No. 21, and national prototype kilogramme, No. 4, from Paris to Washington; descriptions and certificates of these prototypes.	24, quarto.

II.

A SUBJECT-INDEX TO THE PROFESSIONAL PAPERS CONTAINED IN THE ANNUAL REPORTS, IN THE BULLETINS, AND IN THE OCCASIONAL PUBLICATIONS OF THE U. S. COAST AND GEODETIC SURVEY FROM 1845 TO 1890, INCLUSIVE.

KEY TO INDEX.

GEODESY:
- Base lines and standards of length.
- Reconnaissance.
- Triangulation and instruments.
- Time.
- Latitude.
- Longitude.
- Azimuth.
- Arc measures and local deflection of the plumb line.
- Gravity.
- Geographical positions and projections.
- Geographical explorations.

HYPSOMETRY:
- Spirit leveling.
- Trigonometric and barometric heights.

SURVEYING:
- Topography.
- Hydrography.

PHYSICAL HYDROGRAPHY:
- Tides, currents, winds, and shore-line changes due to action of the sea.
- Gulf-stream explorations.
- Deep-sea soundings, temperatures, and densities.
- Surveys and explorations of oyster beds.

TERRESTRIAL MAGNETISM.

ASTRONOMY.

MATHEMATICS.

DRAWING, ENGRAVING, AND ELECTROTYPING.

MISCELLANEOUS.

GEODESY.

BASE LINES AND STANDARDS OF LENGTH.

Year.	Appendix.	Pages.	Subject and author.
1854	35	103–108	Base-measuring apparatus, description of, as used in the Coast Survey.—Lieut. E. B. Hunt, U. S. Engineers.—[Sketch 54.]
1855	41	264–267	Preliminary base apparatus.—C. O. Boutelle.—[Sketch 53.]
1856	60	308–310	Subsidiary base apparatus. Description of a modification devised for ascertaining the temperature of rods in use.—[Sketch 64.]
1857	26	302–305	Epping base, Maine.—A. D. Bache. Notes on the preparation of site, measurement of line, and progress, as compared with other measurements of the Coast Survey.—[Sketch 3.]
1857	45	395–398	Base apparatus for measuring subsidiary lines; description.—J. E. Hilgard.—[Sketch 69.]
1862	26	248–255	Base-measuring apparatus.—J. E. Hilgard. Results of experiments for determining the length and rate of expansion by heat of the six-metre standard bar, with table of comparisons of standard bar with six metres.—[Sketch 49.]

A subject-index to the professional papers contained in the annual reports, etc.—Continued.

GEODESY—Continued.

BASE LINES AND STANDARDS OF LENGTH—Continued.

Year.	Appendix.	Pages.	Subject and author.
1864	14	120–144	Epping base line.—C. A. Schott. Report on the method of computation and resulting connection with the primary triangulation.—(1) General remarks on the method of reduction; (2) instruments and methods of horizontal measures employed in the triangulation near the Epping base; (3) determination of probable error and weight to each direction observed with the 30-inch theodolite; station Howard; abstract of remaining differences; abstract of remaining errors; table; (4) determination of probable error and weight to each angle and direction from observations with a repeating circle; (5) resulting horizontal angles from the observations at each station, with their probable error; (6) effects upon the horizontal angles of a difference of level between the stations occupied and observed upon; (7) spherical excess of triangles; (8) residuals in the sum of angles of each triangle, and their discussion; (9) final determination of probable errors (and weights) to each direction; (10) relative value of results from the 30-inch and the 10-inch repeating theodolites; (11) formation of the conditional equation of the nonagon around the Epping base; (12) equation of correlatives and normal equations; (13) resulting correction to the observed directions; (14) complete adjustment of the nonagon and final directions; (15) triangle side computations; (16) resulting distances from Mount Desert to Humpback; (17) connection of the azimuth mark with the adjusted directions.—[Errata, 143: 1866, p. 141.]
1865	21	187–203	Results of the primary triangulation of the coast of New England, from the northeastern boundary to the vicinity of New York; length and accuracy of the Fire Island base line; length and accuracy of the Massachusetts base line; length and accuracy of Epping base line; geodetic connection of the three primary base lines in Maine, Massachusetts, and New York; their degree of accordance and resulting accuracy of the primary triangulation intervening; resulting angles and distances of the primary triangulation between the Epping, Massachusetts, and Fire Island base lines.—[Errata, 198: 1866, p. 141.]
1866	8	49–54	Primary triangulation of the Atlantic coast.—C. A. Schott. Geodetic connection of the two primary base lines in New York and Maryland, their degree of accordance and accuracy of the primary triangulation intervening, with the resulting angles and distances as finally adjusted.
1866	8	140	Length of the Kent Island base line.—[Supplement to C. A. Schott's report on primary triangulation of the same year.]
1867	7	134–137	Comparison of metres.—F. A. P. Barnard and H. Tresca. Comparison of an iron metre forwarded to France by the Government of the United States of America; Table I, the United States metre upon the comparator; II, the Conservatoire standard upon the comparator; III, the United States metre upon the comparator; IV, results.
1868	7	133–139	Full explanation of the different successive operations connected with the measurement of a subsidiary base line.
1869	6	105–112	Connection of the primary base lines on Kent Island, Md., and on Craney Island, Va., and on the degree of accuracy of the intervening primary and subprimary triangulations.—C. A. Schott. Statistics of conditions; linear discrepancies in the base lines; degree of accuracy; final correction of directions; adjustment of the subprimary stations; Cape Charles Light and North end of measurement; adjustment of the secondary station, Hampton Seminary; table of Atlantic series of primary triangles continued.
1873	12	123–131	Peach Tree Ridge base, near Atlanta, Ga.—C. A. Schott. Measurement of line in 1872, 1873, by C. O. Boutelle (Sketch No. 18); condition of the apparatus; comparison of the tubes; synopsis of results; table of horizontal distances measured between temporary marks near the monuments in each of the three measures; corrected distances; discrepancies in the three measures; heights above mean half tide; probable error of computed length; comparison with the accuracy of other base lines.
1873	12	132–136	Description of the compensation base apparatus of the United States Coast Survey.—E. B. Hunt. (Reprinted from Appendix No. 35, Coast Survey Report of 1854.)
		136	Supplement.—The "Borda thermometer" attachment.

A subject-index to the professional papers contained in the annual reports, etc.—Continued.

GEODESY—Continued.

BASE LINES AND STANDARDS OF LENGTH—Continued.

Year.	Appendix.	Pages.	Subject and author.
1876	22	402–406	The relations of the lawful standards of measure of the United States to those of Great Britain and France.—J. E. Hilgard. Measures of weight, of capacity, of length; relation of yard to metres. Annex I. An act to authorize the use of the metric system of weights and measures; measures of length, of surface, of capacity, weights. Annex II. Comparison of yards and metres.
1877	12	148–181	Comparison of American and British standard yards.—J. E. Hilgard. (1) Relation of the lawful standards of measure of the United States to those of Great Britain and France; measures of weight, capacity, length; relation of yard to metre; annex I, Resolution of Congress providing for the distribution of weights and measures; II, An act to authorize the use of the metric system of weights and measures, measures of length, surface, capacity, weights; annex III, comparison of yards and metres; (2) description of the Troughton 86-inch scale; (3) description of British standard yards, bronze No. 11, and iron No. 57. Coefficient of expansion of the British standard yard bar, bronze No. 11; being a new discussion of the experiments of Sheepshanks and Clarke.—By J. Homer Lane. The relative expansion of bronze 12, and Low Moor iron; for absolute expansion of bronze 12 and brass 2; equations of condition; recapitulation; addendum by O. H. Tittmann; (5) relative lengths of bronze yard No. 11 and iron yard No. 57; experimental comparisons on the dividing machine; comparison on line and end comparator; on the beam compass comparator; comparisons of British bronze yard No. 11 with the Imperial yard and other standards of Great Britain; (1) comparisons with standards of the Dominion of Canada; abstract of comparisons between No. 11 and No. 16; between No. 11 and Dominion Standard A; between Dominion Standard A and No. 16; comparisons with the Imperial yard and other standards of the Standard Office, Westminster, London; rates of expansion; results of comparison of bronze No. 11 (U. S.) with bronze No. 1 (Imperial yard); of No. 11 with bronze No. 6 (Generator); of No. 11 with cast iron B and C; tabulation of results of comparison between No. 11 and foreign standards; (7) comparison of the Troughton scale with the British bronze standard No. 11; (8) concluding statement.
1880	17	341–344	Base apparatus.—J. E. Hilgard. An account of a perfected form of the contact slide base apparatus used in the Coast and Geodetic Survey.—[Sketch 82, Figs. 1 to 8.]
1881	12	354–356	On the length of a nautical mile.—By J. E. Hilgard, Superintendent Coast and Geodetic Survey.
1881	13	357–358	On a method of readily transferring the underground mark at a base monument.—By O. H. Tittmann, Assistant.
1882	7	107–138	Description and construction of a new compensation base apparatus, with a determination of the length of two 5-metre standard bars.—By C. A. Schott, Assistant.
1882	8	139–149	Report of the measurement of the Yolo base, Cal.—George Davidson, Assistant.
1883	11	273–288	Results for the length of the primary base line in Yolo County, Cal. Measurement in 1881 by George Davidson, Assistant. Computation and discussion of results by Charles A. Schott, Assistant.
1889	6	179–197	Relation between the metric standards of length of the U. S. Coast and Geodetic Survey and the U. S. Lake Survey.—By C. A. Schott and O. H. Tittmann, Assistants. Introduction; the Committee metre; the Repsold metre of 1876; the Berlin metre No. 49, special use of; the Toise du Pérou; reasons for presenting results of comparisons; comparison of the Repsold metre of 1876 (R. M.), U. S. Lake Survey, and the Committee metre (C. M.), U. S. Coast and Geodetic Survey; description of the optical beam compass comparator; micrometers; micrometer values; illumination; thermometers; comparison of line and end metres; special device used with C. M.; two plates illustrating same; places of observation; general adjustments; discussion of results; comparison of the coefficients of expansion of the iron Committee metre (C. M.) and of the Repsold steel metre (R. M.); comparison of the Repsold metre of 1876 (or R. M.) with the Berlin metre No. 49 (or B. M.); recapitulation of resulting normal differences R. M. — B. M.; comparison of values for coefficient of expansion of the Berlin brass metre No. 40 (or B. M.);

A subject-index to the professional papers contained in the annual reports, etc.—Continued.

GEODESY—Continued.

BASE LINES AND STANDARDS OF LENGTH—Continued.

Year.	Appendix.	Pages.	Subject and author.
			relation of the Committee metre to the Métre des Archives and to the new International Prototype metre. Abstract of Record of Comparisons: A.—Record of comparisons between the Committee metre (C M.) and the Repsold metre (R. M.). B.—Record of comparisons between the Berlin metre (B. M.) and the Repsold metre (R. M.); abstract of comparisons between C. M. and R. M.; abstracts of results of comparisons between C. M. and R. M.; final abstract R. M.—C. M.; abstract of results of camparisons between B. M. (No. 49) and R. M.
1889	....	165–173	Bulletin No. 17. The relation between the metric standards of length of the U. S. Coast and Geodetic Survey and the U. S. Lake Survey. A report by C. A. Schott and O. H. Tittmann, Assistants, Coast and Geodetic Survey.
1889	10	217-231	Report on the measurement of the Los Angeles base line, Los Angeles and Orange counties, Cal., by George Davidson, Assistant. Previous base measurements at Los Angeles; search for base monuments; desirability of new base measurements; reconnoissance and examination for base-line site; preparations for the measurement; general location of the Los Angeles base line; final location of the line; building the base piers; marking the base stations; the reference or witness marks for the southeast base station; the base line leveled and preliminarily measured with 100 metre wire; half-kilometre marks and temporary marks on the base line; the movable cover for the base apparatus; the organization and movement of the party; foot plates of the trestles; comparisons of the base bars Nos. 1 and 2, and the field standard No. 2; comparisons during the base measurement; placing the forward bar in position; moving the bars into line; measure for fractional bars; the alignment of the bars; the comparators; the operation of a day's measurement; the rate of measurement of the base; tabulation of daily work; first measurement Los Angeles base line; second measurement Los Angeles base line; third measurement Los Angeles base line; summary of the statistics of the three measurements of the Los Angeles base line; exhibit of the third measurement by days. Illustrations: No. 20, Markings of ends of primary base line, Los Angeles, Cal; No. 21, Map showing the general location of the Los Angeles base line and its connection with the main triangulation; No. 22, Profile of the Los Angeles base line; No. 23, Los Angeles base line, sketch showing movement of party.
1889	....	45–50	Bulletin No. 9, on the relation of the yard to the metre.—By O. H. Tittmann, Assistant.
1889	....	157–159	Bulletin No. 15, Verification of weights and measures.—By O. H. Tittmann, Assistant. (One illustration.)
1889	17	479–491	Report on the resulting length and probable uncertainty of five principal base lines, measured with the Bache-Würdemann compensation base apparatus between 1847 and 1855.—By Charles A. Schott, Assistant. Introductory remarks: Part I—Resulting length and probable uncertainty of the base line measured on Dauphine Island, Alabama, in 1847—by A. D. Bache, Superintendent U. S. Coast Survey; Part II—Resulting length and probable uncertainty of the base line measured on Bodies Island, North Carolina, in 1848—by A. D. Bache, Superintendent U. S. Coast Survey; Part III—Resulting length and probable uncertainty of the base line measured on Edisto Island, South Carolina, in 1850—by A. D. Bache, Superintendent U. S. Coast Survey; Part IV—Resulting length and probable uncertainty of the base line measured on Key Biscayne, Cape Florida, in 1855—by A. D. Bache, Superintendent U. S. Coast Survey; Part V—Resulting length and probable uncertainty of the base line measured at Cape Sable, Florida, in 1855—by A. D. Bache, Superintendent U. S. Coast Survey.
1890	16	715–720	On the relation of the yard to the metre.—By O. H. Tittmann, Assistant. NOTE.—This paper is a second edition of Bulletin No. 9, revised by the author, with statement of later comparisons, confirming his results.

A subject-index to the professional papers contained in the annual reports, etc.—Continued.

GEODESY—Continued.

RECONNAISSANCE.

Year.	Appendix.	Pages.	Subject and author.
1850	23	106–110	Extract from the report of Assistant F. H. Gerdes to the Superintendent on the reconnaissance of the Florida Keys, etc.
1850	31	119–120	Report accompanying a reconnaissance chart of the western coast of the United States, from Monterey, Cal., to the Columbia River, Oregon.—By Lieut. Commanding, W. P. McArthur, U. S. N., Assistant.
1851	31	488–494	Florida coast reconnaissance.—F. H. Gerdes. A, description; B, survey; C, tides and currents; D, railroad across the peninsula; E, lighthouses and buoys; F, general remarks on Cedar Keys Harbor.—[Sketches 27, 28, and 29.]
1852	12	87–94	Extracts from the report of Assistant F. H. Gerdes on a reconnaissance from Suwannee River, Florida, to Delta of Mississippi.
1852	18	104–107	Report of Lieut. Commander James Alden, U. S. N., on the reconnaissance from San Francisco to San Diego, including Santa Barbara Islands and channel.
1854	20	28–30	Extracts from the report of F. H. Gerdes on the reconnaissance of the coast of Louisiana in 1854 (Mississippi Delta).
1854	21	30–31	Extracts from a report by W. E. Greenwell on the general features and peculiarities of the coast of Lower Texas, with suggestions in regard to facilities for navigation, from the harbor of the Brazos de Santiago to the mouth of the Rio Grande.
1855	25	171–176	Florida Keys. Survey for the General Land Office, including reports on the general topography and triangulation, on the determination of the shore-line, and reconnaissance of Barnes' Sound, Florida.
1856	52	286–289	Report of the Superintendent to the Commissioner of the General Land Office on progress made in the survey and marking in quarter sections.
1857	41	379–382	Florida Peninsula air-line. Report of a reconnaissance made between Fernandina and Cedar Keys.—By Capt. J. H. Simpson, United States Topographical Engineers.
1857	42	382–390	Florida Keys. Superintendent's report to Commissioner of General Land Office on progress made in survey and marking of the keys.
1857	43	390–391	Coast of Santa Barbara Channel. Report of Subassistant W. M. Johnson on its topographical characteristics.
1857	44	392–395	Santa Barbara Islands and main. Report on the character and progress of the work.—W. E. Greenwell.
1858	34	224	Eastern coast of Florida, south of St. John's River. Report of Subassistant J. Mechan on local characteristics.
1858	35	225–227	Florida Keys. Superintendent's report to Commissioner of General Land Office on progress made in surveying and marking of the keys—Continued.
1859	32	324–328	Coast of Texas, embracing the shores of Espiritu Santo, San Antonio, and Aransas Bays. Report on a reconnaissance.—S. A. Gilbert.
1860	34	356–357	Corpus Christi Bay and Laguna Madre, Texas. General description and characteristics.—S. A. Gilbert.
1861	29	263–264	Coast of Texas above Galveston Bay. Extracts from a descriptive report.—Capt. George Bell, U. S. A.
1873	11	111–122	Geographical and hydrographical explorations on the coast of Alaska.—W. H. Dall. [Sketch No. 17.] Islands of Attu, Bouldyr, Kyska, Amchitka, Adakh, Atka, Amlia, Four Craters, Agashagok, Unalashka. Sannakh Reefs; Popoff Strait; current observations; azimuths; positions and magnetic declinations, Tables 1 to 16; thermometer, mean for 1873; surface of sea water; 5 fathoms below surface-current observations made on board the Yukon during the voyage from San Francisco to Unalashka, May, 1873; heights of mountains determined in 1873.

A subject-index to the professional papers contained in the annual reports, etc.—Continued.

GEODESY—Continued.

RECONNAISSANCE—Continued.

Year.	Appendix.	Pages.	Subject and author.
1885	10	469–481	On Geodetic Reconnaissance.—By C. O. Boutelle, Assistant. Primary triangulation and base lines; reconnaissance for stations of a primary triangulation; tables of values of curvature and refraction; three-point problem; two-point problem; computation of linear co-ordinates; selection of stations for secondary and tertiary triangulations.—[Illustrations 27, 28.]

TRIANGULATION AND INSTRUMENTS.

Year.	Appendix.	Pages.	Subject and author.
1855	57	361–363	Boutelle's tripod and scaffold.—C. O. Boutelle. Description of, as constructed and used by him at the stations of the primary triangulation in Section V.—[Sketch 52.]
1855	58	363–364	Farley's signal.—J. Farley. Description and drawing of a convenient signal for observing on secondary stations —[Sketch 52.]
1855	59	364	Sands's heliotrope.—B. F. Sands. Description and drawing of a convenient signal for observing on secondary stations.—[Sketch 55.]
1856	56	291–292	Mississippi Sound.—J. E. Hilgard. Details of the work of triangulation; signals and station marks.
1856	61	310–315	Theodolite test.—J. E. Hilgard. Examination and trials made of a 10-inch theodolite, applicable to the testing of instruments of like construction.—Table I, readings of every 10° on the circle, and determination of angular distance of verniers; II, determination of eccentricity; III, residual errors of graduation and readings; figure of pivots.
1860	35	357–361	Repeating theodolite. Supplement to the method of testing (described in the preceding paper.)—Table I, readings of every 10° on the circle, and determination of angular distance of verniers; II, determination of eccentricity; III, residual errors of graduation and readings.
1867	9	140–144	Railways, on the use of, for geodetic surveys.—J. E. Hilgard. Wheel records; linear measurement; rectification of curves; reduction of the measured lines and angles to a simpler system.—[Sketch 26.]
1867	10	145	Reflector.—J. E. Hilgard. Description of a new form of geodetic signals.—[Sketch 26.]
1868	7	109–139	Memoranda relating to the field work of a secondary triangulation.—R. D. Cutts. Selection of stations; names of stations; signals; tripods and scaffolds; underground station marks; surface station marks; observations and records; number of observations; limit of error; probable error; reduction to center; correction for phase; correction for eccentricity; spherical excess; distribution of error; trigonometrical leveling; coefficient of refraction; three-point problem; rectangular co-ordinates; measurements of subsidiary base lines; records, duplicates, and computations.
1868	8	140–146	Method of adjustment of the secondary triangulation of Long Island Sound.—C. A. Schott. Example of reduction of angular measure of Shelter Island; final computation and proof of correctness.
1871	15	185–188	Adaptation of triangulations to the various conditions of configuration and character of the surface of country and other causes.—C. A. Schott.
1873	13	137	Intervisibility of stations.—J. E. Hilgard.
1874	15	153	Improved clamp for telescope of the theodolite.—George Davidson.
1875	17	279–292	Method of closing a circuit of triangulation under certain conditions.—C. A. Schott, M. A. Doolittle. Illustrations.
1876	20	391–399	Adaptation of triangulations to various conditions depending on the configuration or orthographic character of a country, and on the degree of accuracy aimed at, with due consideration of the time and means available; also notes on the method of observing horizontal angles and directions in geodetic surveys —C. A. Schott. [Reprinted, with additions, from Report for 1871, Appendix No. 15.]

A subject-index to the professional papers contained in the annual reports, etc.—Continued.

GEODESY—Continued.

TRIANGULATION AND INSTRUMENTS—Continued.

Year.	Appendix.	Pages.	Subject and author.
1877	11	114–147	An examination of three new 20-inch theodolites—J. E. Hilgard. Examination of No. 113; of Nos. 114 and 115; subdivisions on limb of No. 114; of No. 115; example of record; graphic projection of ϵ sin $(r-\rho)$; examination of limb of No. 114; Tables I, II, III (first set); Tables I. II, III (second set); Tables I, II, III (third set); residual errors of graduation and reading; examination of limb of No. 113; Tables I, II, III (first set); Tables I, II, III (second set); Tables I, II, III (third set); residual errors of graduation and reading; examination of limb of No. 115; Tables I, II, III (first set): Tables I, II, III (second set); Tables I, II, III (third set); residual errors of graduation and reading; examination of limbs of 20-inch theodolites with reference to periodicity of errors within 5°; specimen of record (No. 114); mean value of 5′ spaces; of degrees.
1877	13	182	Improved open vertical clamp for telescopes of theodolites and meridian instruments.—George Davidson.
1877	....	45	Field work of the triangulation.—By R. D. Cutts, Assistant. [Reprinted, with additions, from the Coast Survey Report for 1868.]
1878	8	92–118	Primary triangulation between the Maryland and Georgia base lines.—C. A. Schott. Arrangement of errors in closing triangles, in tabular form; average probable error. Paper 1. Adjusted primary triangles between Kent Island, Maryland, and Atlanta, Ga.; (2) estimation of the probable accuracy of a triangulation or approximate determination of the average probable error of the adjusted differences; (3) paper by M. H. Doolittle; I, general method of solution of normal equations; II, addition of new equations; III, order of solution; IV, selection of angle equations; V, treatment of small angles; example.
1880	8	96–109	Geodetic night signals.—C. O. Boutelle. Considerations; different kinds of lights; conditions of the problem; experiments in North and South Carolina; operations at Sugar Loaf Mountain in 1879; method of observing; comparison of day and night observations; additional expense in using night signals; offsets to the expense; conclusions; sketches Nos. 36, 37.
1882	9	151–197	Field work of the triangulation, third edition.—R. D. Cutts, Assistant.
1882	10	199–208	On the construction of observing tripods and scaffolds.—C. O. Boutelle, Assistant.
1884	8	377–385	The run of the micrometer.—By George Davidson, Assistant. Explanation of the expression in reference to an astronomical or geodetic instrument; conditions when a micrometer has and when it has not a run; discussion of formulæ for the determination of run, with examples; tabulation of the micrometer runs observed at station Northwest Yolo Base; tables of the corrections for the "run of microscope micrometers."
1884	9	387–390	Connection at Lake Ontario of the primary triangulation of the Coast and Geodetic Survey with that of the Lake Survey.—Observations by Charles O. Boutelle, Assistant. Discussion by Charles A. Schott, Assistant. Probable errors of the horizontal directions of the Coast and Geodetic Survey; summary of resulting directions at Mount Hamilton; differences in the linear values of the lines Sodus-Oswego, Victory-Oswego, and Clyde-Victory; differences in the longitudes and latitudes of the stations Sodus and Oswego, and differences in the azimuth of the line Sodus to Oswego, as determined by the Coast and Geodetic Survey and the Lake Survey; comparisons of the mean error of an angle as determined by each survey; junction in Illinois of the Coast and Geodetic Survey; transcontinental triangulation (through Assistant Fairfield's field computation) and the Lake Survey arc of the meridian, vicinity of the Olney base.—[Illustration 20.]
1885	9	441–467	Results deduced from the geodetic connection of the Yolo base line with the primary triangulation of California; also a reduction and adjustment of the Davidson quadrilaterals, forming part of that triangulation.—By Charles A. Schott, Assistant. Prefatory note; sketch of Yolo base connections; description of instruments used and method of observation; abstract of the horizontal directions resulting from the local adjustment at each of the stations composing the Yolo base net of triangulation; determination of weights to directions in the adjustment of the triangulation; table of closing errors of the triangles forming the Yolo base figure, arranged in the order of the size of the triangles with the probable error

A subject-index to the professional papers contained in the annual reports, etc.—Continued.

GEODESY—Continued.

TRIANGULATION AND INSTRUMENTS—Continued.

Year.	Appendix.	Pages.	Subject and author.
			of a direction; adjustment of a triangulation net or of conditioned observations; application to the adjustment of the Yolo base net; correlative equations; normal equations Yolo base net with solutions; determination of the probable error of the adjusted length of the primary side. Mount Helena to Mount Diablo; triangle side computation; formulæ for the computation of geodetic latitudes, longitudes, and azimuths sufficiently precise for sides of the largest triangles that may be directly measured; determination of standard geodetic data for the computation of geographical positions; geodetic or standard latitude of Mount Helena, and geodetic or standard azimuth of direction, Mount Helena to Mount Diablo, for the Davidson quadrilaterals, geodetic results of the Davidson quadrilaterals, introducing the Yolo base into the primary triangulation of California.

TIME.

Year.	Appendix.	Pages.	Subject and author.
1854	39	121	Discussion of probable error of observation with a Würdemann 26-inch portable transit; from observations by G. Davidson in 1853. [Report of 1866, Sketch 29.]—J. E. Hilgard.
1865	15	152–154	Report, with tables, on the declinations and proper motions in declination of standard time stars.—B. A. Gould.
1865	16	155–159	Report, with tables, of the positions and proper motions of the four polar stars.—B. A. Gould.
1866	9	55–71	The transit instrument, description, use, adjustment, and method of observation.—C. A. Schott.
1867	8	138–139	New meridian instrument for time, latitude, and azimuth.—George Davidson.—[Sketch 28.]
1868	10	154–157	Addenda to Appendix No. 9, Coast Survey Report for 1866, on the determination of time by means of the transit instrument.—C. A. Schott.
1869	12	226–232	On the use of the zenith telescope for observations of time, with an example of observation.—J. E. Hilgard.
1872	12	222–226	Determination of weights to be given to observations for determining time with portable transit instrument, recorded by the chronographic method.—C. A. Schott. Relative weights to transits depending on the star's declination; relative weights to incomplete transit observations; reduction of observations for time.
1872	18	266	Improvement on the Hipp chronograph.—William Eimbeck.
1874	17	156–159	Two forms of portable personal equation apparatus.—J. E. Hilgard. Examples of observations; observations for absolute personal equation; diagrams.
1874	....	32	Field catalogue of 983 stars, for time observations; mean places for 1870.—George Davidson.
1874	....	69	Star factors A, B, and C, for reducing transit observations.—George Davidson.
1875	15	249–250	Description of an apparatus for recording the mean of the times of a set of observations. (Diagram.)—C. S. Peirce.
1877	13	182, 183	Improved open vertical clamp for telescopes of theodolites and meridian instruments.—George Davidson.
1879	7	103–109	Description of the Davidson meridian instrument.—George Davidson. See Appendix No. 8, report of 1867, for first printed description.
1880	14	205–227	Determination of time by means of the transit instrument. (Four plates.)—C. A. Schott. General remarks; description; adjustment; method of observation; equatorial intervals of threads; incomplete transits; corrections for rate of chronometer, for inclination, for inequality of pivots, for collimation, for deviation, for diurnal aberration; personal equation; chronometer correction; reduction of observations by least squares; probable error; example; weights; preparation for observing transits; example of record and computation of inequality of pivots; specimen of record for value of level by level-trier; tabulation of factors; table of factors for reduction of transit observations.

A subject-index to the professional papers contained in the annual report, etc.—Continued.

GEODESY—Continued.

TIME—Continued.

Year.	Appendix.	Pages.	Subject and author.
1883	18	383-472	Field catalogue of 1278 time and circumpolar stars; mean places for 1885·0.—By George Davidson, Assistant.
1885	15	503-508	Note on a device for abbreviating time reductions.—By C. S. Peirce, Assistant.
1889	9	213-216	Description of two new portable transits for longitude work.—By Edwin Smith, Assistant. One illustration. (Published also as Bulletin No. 16.)

LATITUDE.

Year.	Appendix.	Pages.	Subject and author.
1852	....	16	Notes on the use of the zenith telescope in determining latitudes in the Coast Survey by Talcott's method, and on the reduction of the observations, by A. D. Bache, Superintendent U. S. Coast Survey. (From the American Journal of Science and Arts, Vol. XIV, second series, New Haven, 1852.)
1855	44	276-278	Description of Würdemann's zenith telescope of 1855, used at Dixmont, Me. —G. W. Dean.
1857	31	324-334	Latitude.—On the method of determination with the zenith telescope.—C. A. Schott. Principle of the method; determination of value of micrometer—examples; determination of value of level—example; correction for refraction—example; reduction to meridian—tables; selection of stars: sources of error in the determination of the value of micrometer; method of correcting value from the latitude observations themselves; discussion of the results of observation—example.
1858	20	184-186	Personal equation.—A. D. Bache. On the use of the zenith telescope for determining latitude by Talcott's method—table showing results of observations for personal equation.
1865	17	160-165	Report on the latitude of Cloverden station in Cambridge.—B. A. Gould. Micrometer values; reduction of star observations—tables; discrepancies with uncorrected catalogue places—table; resultant mean places of stars, etc.—table; deduced places for Cloverden station—table; mean error; other determinations.
1866	10	72-85	Latitude by the zenith telescope.—C. A. Schott. (1) General remarks on Talcott's method; (2) modification of instrument; (3) description; (4) adjustment; (5) selection of stars for observation; (6) directions for observing; (7) off the meridian; (8) general expression for the latitude; (9) determination of the value of a division of micrometer; (10) of level; (11) correction for differential refraction; (12) reduction to the meridian; (13) record of the observations; (14) reduction of the observations; (15) discussion of the results; (16) combination of the results by weight.—Examples to articles 9, 10, 13, and 14.—[Sketch 28.]
1867	8	138-139	New meridian instrument for time, latitude, and azimuth.—George Davidson.—[Sketch 28.]
1873	14	138	List of stars for latitude observations.
1876	7	83	A catalogue of stars for latitude observations.
1877	13	182-183	Improved open vertical clamp for telescopes of theodolites and meridian instruments.—George Davidson.
1879	7	103-109	Description of the Davidson meridian instrument.—George Davidson. See Appendix No. 8, Report of 1867, for first printed description.
1880	14	245-259	Latitude determination by means of the zenith telescope.—C. A. Schott. (1) General remarks on Talcott's method; (2) modification of instrument; (3) description; (4) adjustment; (5) selection of stars; (6) directions for observing; (7) bisection of stars off the meridian; (8) general expression for latitude; (9) determination of value of micrometer; (10) determination of value of level; (11) differential refraction; (12) reduction to the meridian; (13) form of record; (14) of reduction; (15) discussion of results; (16) combination of results by weights.—Examples to articles 9, 10, 13, and 14.

A subject-index to the professional papers contained in the annual reports, etc.—Continued.

GEODESY—Continued.

LATITUDE—Continued.

Year.	Appendix.	Pages.	Subject and author.
1888	13	465–470	Differential method of computing the apparent places of stars for determinations of latitude, by E. D. Preston, assistant.
1888	14	471-563	Determinations of latitude and gravity for the Hawaiian Government, by E. D. Preston, assistant. [For abstract of contents see under "Gravity."]
1889	....	137–142	Bulletin No. 11.—An abstract of above paper published in advance of the appearance of the full paper in the report for 1888.

LONGITUDE.

Year.	Appendix.	Pages.	Subject and author.
1846	10	71–72	Differences of longitude of Philadelphia and Greenwich, by reduction of observations at Cambridge, Mass.—S. C. Walker.
1846	11	72–74	Differences of longitude by telegraph.—S. C. Walker. Correction for personal equation.
1848	....	6	Letter from Professor Bache to the editor of the Astronomische Nachrichten, dated at Washington, February 7, 1848, and communicating a report of Prof. Sears C. Walker of November 10, 1847, on the results obtained in the Survey of the Coast of the United States for differences of longitude by the electro-magnetic telegraph.—Prof. Schumacher's Astronomische Nachrichten, No. 632.
1848	4	78–83	Recapitulation of results for personal equation, 1844–1848.—S. C. Walker.
1848	19	112–118	Longitude computations.—S. C. Walker.
1848	....	13	Letter of A. D. Bache, Superintendent U. S. Coast Survey, to the Secretary of the Treasury, dated December 26, 1848, communicating a report by S. C. Walker, on an application of the galvanic circuit to an astronomical clock and telegraph register in determining local differences of longitude and in astronomical observations generally. [House Ex. Doc. No. 21, Thirtieth Congress, second session.]
1849	5	72–78 74	Mechanical record of astronomical observations.—Prof. O. M. Mitchel. Revolving disk; arrangement for recording differences of declinations,
1850	6	79	Differences of longitude between Cambridge and Liverpool observatories.—W. C. Bond.
1850	13	85–89	Telegraphic operations and computations.—S. C. Walker. I, Experiments for galvanic wave time between Washington and St. Louis; II, attempted experiments on wave time through different conductors; III, experiments with the chemical telegraph line; IV, progress of the researches on the velocity of the galvanic current; the Bond spring governor.
1851	18	462-463	Telegraphic arrangement to determine the difference of longitude between Cambridge and Halifax.—S. C. Walker.
1851	25	476–479	Measures of wave time, made from 1849 to 1851.—S. C. Walker. Specifications and tables of results.
1851	26	480–481	Abstract of reports on longitudes.—S. C. Walker. By moon culminations, eclipses, transits, occultations, and telegraph.
1853	31	84	On longitude from moon culminations.—Benjamin Peirce. On the determination of longitude from observation of moon culminations; standard probable error of observation of interpolated lunar transits: constant errors of epoch and periodical one of half lunations.
1853	32	84–86	On moon culminations observed by the "American method," with remarks on the performance of Bond's spring governor.—W. C. Bond. Comparison of records made by two spring governors differing one-tenth of a second in time of vibration of their respective pendulums; table of star transits; amount of probable errors.
1853	33	86–88	Telegraphic longitude of Charleston, S. C.—B. A. Gould. Results of observations for the determination of difference of longitude by telegraph between Seaton station (Washington, D. C.) and Charleston, S. C.

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GEODESY—Continued.

LONGITUDE—Continued.

Year.	Appendix.	Pages.	Subject and author.
1853	....	88–89	Cambridge and Liverpool chronometer expeditions in 1849, 1850, and 1851.—G. P. Bond. Computations of results for determining difference of longitude.
1854	36	108–120	Longitude by moon culminations.—Benjamin Peirce. General considerations; constant errors and personal equations; correction of the lunar ephemeris; standard probable error of observation of a lunar transit; limit of accuracy attainable; longitude of the National Observatory, Washington, D. C.; three forms of correcting lunar ephemeris and the modes of computation.—[Errata, 112, 113, 114, 115, 117: 1855, p. xix.]
1854	37	120	Moon culminations.—W. C. Bond. Observed by the American method; chronometric longitude of Cambridge and probable error.
1854	38	120	Moon culminations.—E. O. Kendall. Observed at High School observatory, Philadelphia.
1854	39	121	Discussion of probable error of observation with a Würdemann 26-inch portable transit. From observations by G. Davidson in 1853. [See illustration No. 29—Report 1866.]—J. E. Hilgard.
1854	41	128–131	Telegraphic longitude.—B. A. Gould. On telegraphic observations for the difference of longitude between Raleigh, N. C., and Columbia, S. C.
1854	42	138–142	Chronometric longitude expeditions (Cambridge-Liverpool).—G. P. Bond. Results of the expeditions of 1849, 1850, and 1851, and on the method of computation.—[Errata, 140: 1855, p. xix.]
1855	42	267–274	Longitudes.—Report on the method of determining longitudes by occultations of the Pleiades.—Benjamin Peirce. [Errata, 268, 269, 270, 272, 273: 1855, p. xviii.]
1855	43	275–276	Chronometric longitudes.—W. C. Bond. On moon culminations observed by him, and the chronometric expedition for determining the longitude difference between Cambridge, Mass., and Liverpool, England.—[Errata, 275: 1855, p. xviii.]
1855	46	286–295	Telegraphic longitudes.—B. A. Gould. Report on telegraphic operations for difference of longitude between Columbia, S. C., and Macon, Ga.; programme of telegraphic campaign; for instrumental corrections and longitude reductions; battery memoranda; to put up Kessel's clock.—[Errata, 288: 1855, p. xviii]
1856	20	163–166	Telegraphic longitudes.—B. A. Gould. Operations for difference of longitude between Wilmington, N. C., and Montgomery, Ala., with list of stars for observation.
1856	21	167–181	Telegraphic method of determining differences of longitude.—G. W. Dean. Details of the method used in the Coast Survey for telegraphic determinations of difference of longitude; transit instrument; astronomical clock; chronographic register; batteries; list of stars arranged from the British Association Catalogue for determining the difference of longitude between Macon, Ga., and Montgomery, Ala., March, 1856; exchange of star signals; reading off the chronographic sheets; example of reduction; observations for determining the inequality of the pivots of Coast Survey transit No. 8; personal equations. (Sketch 66).—[Errata, 169–170: 1856, p. xx.]
1856	22	181	Chronometric and astronomical longitudes.—W. C. Bond. On longitude-computations and occultations observed; lunar-spot transits.
1856	23	182–191	Chronometric results.—G. P. Bond. Results of the chronometric expeditions of 1849, 1850, 1851, and 1855 for difference of longitude between Cambridge, Mass., and Liverpool, England; table of longitudes by voyages of 1855.
1856	24	191–197	Pleiades.—Benjamin Peirce. On the determination of longitude by occultations of the Pleiades; formulas for the correction of the co-ordinates of the stars; table for 1840; table of logarithms for *h* and *k* for the principal observatories.
1856	25	198–203	Lunar-spot transits.—C. H. F. Peters. On the substitution of lunar spots for the moon's limb in observing culminations.

A subject-index to the professional papers contained in the annual reports, etc.—Continued.

GEODESY—Continued.

LONGITUDE—Continued.

Year.	Appendix.	Pages.	Subject and author.
1856	26	203–208	Occultations on the western coast.—G. Davidson. Observations made at Port Townsend, Wash. Ter., April and May, 1856; tables and remarks.
1857	27	305–310	Telegraphic longitudes.—On the progress made in the different campaigns.—B. A. Gould. List of time-stars adopted; difficulties and discrepancies of transmission for signals between Wilmington, N. C., and Columbia, S. C.
1857	28	310, 311	Moon culminations.—W. C. Bond. On the number observed during the year at Cambridge, co-operative with those on the Pacific side; star-occultation photographs; connection with Quebec.
1857	29	311–314	Longitude methods.—Benjamin Peirce. On the relative precision of determinations by occultations and solar eclipses; upon the use of the solar eclipses; upon the occultations of the Pleiades.
1857	30	314–324	Chronometric determination of the difference of longitude between Savannah, Ga., and Fernandina, Fla., and discussion of the method.—A. D. Bache and C. A. Schott. Chronometers used; personal equation; temperature compensation; chronometer comparisons—table; stationary and traveling rates; tables of comparison and discussion.
1858	21	186–189	Longitudes.—Method of computing from moon-culminations; notes on observations of moon-culminations; forms and example.
1858	23	190	Moon-culminations, etc.—O. M. Mitchel. Number of observations made by him for the Coast Survey.
1859	21	278	Moon-culminations.—O. M. Mitchel. Observations made for the Coast Survey at the Cincinnati Observatory for longitude purposes.
1861	16	182–195	Longitude.—Benjamin Peirce. Discussion of observations of the solar eclipse of July, 1851; observations of the total phase; European observations of which the beginning and the end, both observed at the same place, have been admitted into the computation; American observations; method of computation.
1861	17	196–221	Report on the determination of longitude by occultations of the Pleiades, with an example showing the mode of computation; Greenwich, Cambridge (England), Ashurst, Washington City, Philadelphia, and Boston observatories computed; solutions of the equations for the correlation of the moon's place and of the longitude.
1861	18	221–232	Longitude of Albany, N. Y.—B. A. Gould. Abstract of a report on the determination by telegraph of the difference of longitude between New York City and Albany; table of instrumental corrections; collimation and azimuth correction, and hourly clock-rate; personal equations; comparative table of longitude results at the two stations.
1862	12	155, 156	Longitude of America from Europe.—Benjamin Peirce. On the result from occultations of the Pleiades.
1862	13	157, 158	Lunar tables used in reducing observations of the Pleiades for longitude.—Benjamin Peirce. On their progressive improvements.
1862	14	158–160	Longitudes in Maine, Alabama, and Florida.—B. A. Gould. On progress in computing results from telegraphic observations.
1863	17	146–154	Occultations of the Pleiades in 1841–'42.—Benjamin Peirce. On computations for longitude, Nos. I, II, and V; records of Edinburgh, Washington, and Cambridge observations; ephemeris; stereographic co-ordinates of the moon referred to Alcyone; equations for the correction of the moon's place and of the longitude; solutions.
1863	18	154–156	Longitude.—B. A. Gould. On computations connected with the telegraphic method.
1863	23	205	Induction-time in relay-magnets.—G. W. Dean. Report on experiments made to determine their relative power.

A subject-index to the professional papers contained in the annual reports, etc.—Continued.

GEODESY—Continued.

LONGITUDE—Continued.

Year.	Appendix.	Pages.	Subject and author.
1864	11	114	Longitude.—Benjamin Peirce. On the method of determining longitudes by occultations of the Pleiades.
1864	12	115, 116	On results by telegraphic method.—B. A. Gould.
1864	20	211–220	Eduction-time of relay-magnets, deduced from experiments.—G. W. Dean.
1865	12	138–146	Report on the progress of determining longitude from occultations of the Pleiades, continued from previous reports.—Benjamin Peirce. Values of $\Sigma_2 - p$ for 1838–'42 and 1857–'61.
1865	13	146–149	Method of determining longitude from the occultations of the Pleiades, continued from previous reports.—Benjamin Peirce. Corrections of lunar semidiameter, mean place, ellipticity of orbit, longitude of perihelion, coefficient of annual parallax, and longitude of Europe and America; example.
1865	14	150, 151	Report on the results of determining longitude by telegraphic method.—B. A. Gould.
1866	9	55–71	The transit instrument, description, use, adjustment, and method of observation.—C. A. Schott.
1866	12	99, 100	Longitude.—[From Report for 1846.]—S. C. Walker. Difference of longitude between Philadelphia and Greenwich by reduction of Cambridge (Mass.) observations.
1866	13	100–102	Longitude.—[Report for 1846.]—S. C. Walker.
1866	14	102–105	Longitude.—[From Report for 1848.]—S. C. Walker. Difference of longitude between New York, Cambridge, and Greenwich.
1866	15	106–108	Longitudes.—[From report for 1850.]—S. C. Walker. (1) Experiments for galvanic-wave time between Washington, D. C., and St. Louis, Mo.; (2) attempted experiments on wave-time through different conductors; (3) experiments with the chemical telegraph line; (4) progress of the researches on the velocity of the galvanic current.
1866	16	109–111	Galvanic-wave time.—[From Report for 1851.]—S. C. Walker. On measurements from 1849 to 1851, with tables.
1866	17	111, 112	Longitudes.—[From Report for 1851.]—S. C. Walker. Abstract of reports on longitudes, by moon culminations, by eclipses, transits, and occultations, by chronometer expeditions, and by telegraphic operations.
1867	6	57–133	On the longitude between America and Europe from signals through the Atlantic cable.—B. A. Gould. (1) Origin of the Coast Survey expeditions in 1865 and 1866; (2) previous determinations of transatlantic longitudes from eclipses and occultations; from moon-culminations; from chronometers transported from Boston to Liverpool; (3) history of the expedition of 1866; programme of transatlantic-longitude campaign; (4) observations at Valencia; table of equatorial intervals; table of observations, October 25 to November 16, 1866; (5) observations at Newfoundland, October 25 to December 16, 1866; (6) observations at Calais, December 11 to 18, 1866; (7) longitude-signals between Foilhommerum and Hearts Content; clock-corrections; transatlantic longitude and transmission time, October 25 to November 9, 1866; (8) longitude-signals between Hearts Content and Calais; tables of Newfoundland and Calais signals; tables of longitude and times of transmission; (9) personal error in noting signals; (10) personal equation determining time; (11) final results for longitude; (12) velocity of transmission; cables of 1865 and 1866; tables of comparison. [Published also by the Smithsonian Institution, Washington, 1869.]
1870	12	100	Results of the telegraphic determination of the longitude of San Francisco, Cal.
1870	13	101–106	Abstracts of results for difference of longitude between Harvard Observatory, Massachusetts, the Coast Survey station, Seaton, and the Naval Observatory, Washington, D. C., as determined by means of the electric telegraph in 1867 by the U. S. Coast Survey, with the co-operation of Prof. Joseph Winlock, Director of Harvard Observatory, and Commodore B. F. Sands, U. S. N., Superintendent Naval Observatory.

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GEODESY—Continued.

LONGITUDE—Continued.

Year.	Appendix.	Pages.	Subject and author.
1872	13	227–234	Preliminary report on the determination of transatlantic longitudes.—J. E. Hilgard. Brest, Greenwich, Paris; results of observation for personal equation; longitudes; Brest-Greenwich, Brest-Paris, Greenwich-Paris; Brest-St. Pierre-Cambridge; Harvard Observatory-Greenwich; Washington-Greenwich; Washington-Paris.
1873	....	437–477	On the determination of transatlantic longitudes by means of the telegraphic cables.—By Prof. Joseph Lovering, of Harvard College. Smithsonian Contribution to Knowledge, No. 223.
1874	18	163–247	Transatlantic longitudes.—J. E. Hilgard. Final report on the determination of 1872, with a review of previous determinations. Part I—Section I, Cambridge; II, St. Pierre; III, Brest; IV, Paris-Greenwich; V, Cambridge-St. Pierre; VI, St. Pierre-Brest; programme for cable exchanges; VII, personal error in noting cable time signals; VIII, wave time of cable signals; IX, Brest-Paris and Brest-Greenwich; X, personal equation, Blake-Folain; XI, personal equation, Blake-Greenwich standard observer, and longitude Greenwich-Paris; XII, personal equation of Coast Survey observers; XIII, flexure of transit axis; XIV, final discussion of the results for longitude differences, Brest, Greenwich, Paris; XV, final combination of the longitude differences deduced from the observations of 1872, 1870, and 1866; finally adopted longitudes from observations of 1866, 1870, and 1872.
		182	Part II—Reduction of the observations made for the transatlantic longitude determination of 1872; computation of observations for clock and instrumental corrections at Cambridge, Mass., 1872; Cambridge clock corrections, from stars of less than 65° N. declination; computation of observations for clock and instrumental correction at St. Pierre, Miquelon, 1872; St. Pierre clock corrections, from stars of less than 65° N. declination; adopted clock corrections, Cambridge and St. Pierre at the epochs of exchanging longitude signals; table of such clock corrections and rates at St. Pierre as relate to the longitude determination with Brest; computation of observations for clock and instrumental corrections at Brest, Paris, and Greenwich; adopted chronometer corrections from all stars south of 60° N. declination; errors and rates of the sidereal standard clock of the Royal Observatory at Greenwich, connected with the longitude differences, Greenwich-Brest and Greenwich-Paris; computation of observations for clock and instrumental corrections of the National Observatory at Paris, France, relating to the differences of longitude, Paris-Brest and Paris-Greenwich; observations for inclination of axis of the Gambey meridian transit; azimuths of the meridian mark; observations on α, δ, and λ Ursæ Minoris; coefficients employed in the reduction of the observations; observations made with the Gambey meridian transit for difference of longitude, Paris-Brest; clock corrections and hourly rates at Paris; observations with the Gambey meridian transit and the Morse-Digney chronograph for difference of personal equation of Blake-Folain; clock corrections and hourly rates at Paris; observations with the Gambey meridian transit for difference of longitude, Paris-Greenwich; clock corrections and hourly rates at Paris; results of telegraphic time signals exchanged between Cambridge and St. Pierre; between St. Pierre and Brest; between Brest and Paris; between Brest and Greenwich; between Greenwich (Coast Survey transit) and Paris; personal error in noting cable time signals at St. Pierre; at Brest; difference of personal equation of Folain and Blake; Criswick and Blake; personal equation; Goodfellow, Blake, and Smith; observations for personal equation at Cambridge, Mass., October and November, 1872; results. [Errata pp. 163, 164, 167, 168, 169, 172, 173, 177, 178, 180, 207, 237, 242.]
1875	9	139–155	Telegraphic longitude of Key West.—C. A. Schott. Introduction; description of observing stations and of instrumental outfit; relative personal equations; equatorial interval of wires of transit circle; adopted mean places in right ascension of stars observed at Washington and Key West; probable error of clock corrections; reduction of transits for clock corrections, Washington; conditional and normal equations; synopsis of results for correction and rate of clock; reduction of transits for chronometer corrections, Key West; normal equations for azimuth and chronometer corrections; synopsis of results for correction and rate of chronometers; telegraphic connection and exchange of time signals; telegraphic difference of longitude, Washington-Key West; resulting longitude of Key West and of light-houses in its vicinity.

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GEODESY—Continued.

LONGITUDE—Continued.

Year.	Appendix.	Pages.	Subject and author.
1880	6	81–92	Telegraphic longitudes.—C. A. Schott. Report on the results of telegraphic longitudes determined by the Coast and Geodetic Survey up to the present time, and preliminary adjustment by least squares; two groups; specimen of the first group; Atlanta and Washington; results for difference of longitude; review of the telegraphic longitude work; published results; method of combining results; table of results of differences of longitude; table of results determining subordinate stations; combination and adjustment of observed differences of longitude; diagram No. 33, conditional equations; resulting adjusted longitudes (west of Greenwich).
1880	7	93–95	Telegraphic longitudes.—Edwin Smith. Explanation of apparatus used for observation; description; cases 1 to 5; adjustments; interchange of signals; diagrams Nos. 34 and 35.
1880	14	231–241	Determination of longitude by means of the electric telegraph (two plates).—C. A. Schott. (1) Telegraphic determination of longitude; (2) personal equation; specimen of record of results for difference of longitude; variability in personal equation; (3) weights to transit observations recorded on the chronograph; weights depending on the star's declination; weights to incomplete transits; reduction of observations for time; (4) disposition of telegraphic instruments in the observatory; arrangements I to VI; (5) concluding remarks.
1884	11	407–430	Longitudes deduced in the Coast and Geodetic Survey from determinations by means of the electric telegraph, between the years 1846 and 1885. Second adjustment.—By Charles A. Schott, Assistant. Prefatory note; comparison of the state of the longitude work of the Survey in 1880 with that of 1885; growth of the work, with an account of its gradual development in the Survey; explanatory remarks to the table of results; Table I, general table of results for differences of longitude of stations, determined by the U. S. Coast and Geodetic Survey, by means of the electric telegraph, between the years 1846 and 1884 (July); Table II, observed differences of longitude, their probable errors, numbers for reciprocal of weights, and symbolic corrections; degree of accuracy attained by the Survey of late years; adjustment of results by least squares; form of the conditional equations; reduced conditional equations to be satisfied; scheme of coefficients and of inverse weights for the formation of normal equations and for computing the corrections expressed in terms of the correlatives; normal equations; values of C_1 and of δ_1; final values, λ, of longitudes from Greenwich, in accordance with a decision of the International Meridian Conference, held at Washington, October, 1884; comparison of results with those of first adjustment of 1880; tables of longitudes, λ, of the remaining stations, arranged by States and Territories, in alphabetical order; computation of probable errors of adjusted longitudes; determination of the probable errors of the resulting longitudes of Washington, U. S. Naval Observatory, and of Cambridge, Harvard College Observatory; longitude of Detroit, Mich.; comparison of the U. S. Coast and Geodetic Survey result with the longitude used by the U. S. Lake Survey; longitude of Ogden, Utah; comparison of the U. S. Coast and Geodetic Survey result with the value adopted by the U. S. Engineers; junction of the American and European systems of longitudes, with diagram showing connections adjusted.—[Illustration 21.]
1889	....	147–150	Bulletin No. 13.—Telegraphic determination of the longitude of Mount Hamilton, Cal. Field work by C. H. Sinclair, assistant, and R. A. Marr, Subassistant. Report by Charles A. Schott, Assistant.
1889	....	161–164	Bulletin No. 16.—Description of two new transit instruments for longitude work.—Constructed at the office of the Survey from designs by Edwin Smith, Assistant. (One illustration.)
1889	8	209–212	Telegraphic determination of the longitude of a station on Mount Hamilton, Cal., and its trigonometrical connection with the Lick Observatory. Field work by C. H. Sinclair, Assistant, and R. A. Marr, Subassistant. Report by Charles A. Schott, Assistant.
1889	9	213–216	Description of two new portable instruments for longitude work.—Constructed at the office of the Survey from designs by Edwin Smith, Assistant. (One illustration.)

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GEODESY—Continued.

AZIMUTH.

Year.	Appendix.	Pages.	Subject and author.
1856	27	208–209	Azimuth.—J. E. Hilgard. Method of using the transit instrument for azimuth observations; form of record and reduction.
1866	11	86–99	Astronomical azimuth.—C. A. Schott. (1) Principal methods; (2) astronomical azimuth; (3) geodetic azimuth; (4) primary and secondary azimuths; (5) time; (6) instruments used; (7) azimuth marks; (8) errors eliminated; (9) circumpolar stars used; (10) high stars; (11) sets of observations; (12) method of recording and reducing; (13) observations of a close circumpolar star near its elongation; (14) at any hour angle; (15) computation by fundamental trigonometrical formula; (16) by Napier's analogies; (17) by a development into a series; (18) at equal intervals before and after culmination; (19) observation of sun for azimuth; (20) examples of records and reductions to Articles 11, 13, 14, 15, 17, 18, and 19.—[Sketches 26 and 27.]
1868	10	157–165	[Supplement, 1868, p. 157.—Specimen table of local times of elongations and culminations of four circumpolar stars for 1873, latitude 40°, longitude 6h. west of Greenwich; correction for altered dates and latitudes.] [Supplement, p. 158.—In vertical of star; example of record and reduction; micrometer values; deduction of azimuth.] [Supplement, p. 160.—(*a*) Near culmination; example of record and computation; eye-piece micrometer, values determined and applied to level correction; (*b*) pivot micrometer, ditto, with example and record of reduction; single micrometer turn, ditto; discussion of set of four stars; centering of instrument for connection with triangulation.]
1870	17	178–179	Changes of elevation and azimuth caused by the action of the sun at station, Dominguez, Cal.—George Davidson.
1870	22	226–227	Azimuth and apparent altitude of Polaris.—George Davidson.
1880	14	263–280	Astronomical azimuth.—C. A. Schott. [Four plates.] (1) General remarks; (2) instruments; (3) general considerations; (4) methods; (5) observations of a close circumpolar star near elongation; (5*b*) observations with the transit in the vertical of a close circumpolar star, near its elongation; (6) at any hour angle; (7) computation by fundamental formula; (8) by Napier's analogies; (9) by development into series; (10) at equal intervals before and after culmination; (10*b*) near culmination with eye-piece micrometer, corrections; (10*c*) with pivot micrometer; (11) observations of sun for azimuth; (12) examples of record and reduction to Articles 5, 5*b*, 6 and 7, 9, 10, 10*b*; line of collimation by reversal on star; examples to Articles 10*c*, 11; table of local time of elongation and culmination of four circumpolar stars for 1885, latitude 40°, longitude 6h. west of Greenwich.
1890	....	215–218	Bulletin No. 21. Determination of an azimuth from micrometric observations of a close circumpolar star near elongation by means of a meridian or transit and equal altitude instrument, or by means of a theodolite with eye-piece micrometer. Report on method and example of computation by Charles A. Schott, Assistant. Observations by A. T. Mosman, Assistant.

ARC MEASURES AND LOCAL DEFLECTION OF THE PLUMB LINE.

Year.	Appendix.	Pages.	Subject and author.
1868	9	147–153	Results of the measurement of an arc of the meridian.—C. A. Schott. Length of the arc by four methods; accuracy of the preceding results; table and diagram; determination of the astronomical latitudes; recapitulation of results.
1869	7	113–115	Local deflections of the zenith in the vicinity of Washington City.—C. A. Schott.
1877	6	84–95	The Pamplico-Chesapeake arc of the meridian and its combination with the Nantucket and the Peruvian arcs for a determination of the figure of the earth from American measures.—C. A. Schott. Base lines; latitudes; resulting azimuths determined astronomically; conditional equations; combination of arcs of the meridian; resulting conditional equations of each arc of the meridian; Nantucket arc; Pamplico-Chesapeake arc; Peruvian arc; combination of arcs for determining the figure of the earth considered as a spheroid; table of data for figure of the earth, Bessel, 1841, Clarke, 1866, Coast Survey, 1877.

A subject-index to the professional papers contained in the annual reports, etc.—Continued.

GEODESY—Continued.

ARC MEASURES AND LOCAL DEFLECTION OF THE PLUMB LINE—Continued.

Year.	Appendix.	Pages.	Subject and author.
1879	8	110–123	Comparisons of local deflection of the plumb line.—C. A. Schott. Determination of the standard geodetic latitude; table of systematic apparent deflections in the meridian; determination of the standard geodetic azimuth; table of systematic deflection at right angles to the meridian resulting from observed azimuths; determination of the standard geodetic longitude; exhibition of the apparent local deflections of the vertical with reference to the Bessel and Clarke spheroids; table of comparison of effect of apparent local deflection of the vertical in latitude for the Bessel and Clarke spheroids; table of same for deflections in azimuth; in longitude. Appendix A, (Table 1), astronomical latitudes of the oblique arc along the Atlantic; (2) comparison of the register latitudes, apparent deflection in the meridian. Appendix B (Table 1), astronomical azimuths of the oblique arc along the Atlantic; (2) comparison of the register azimuths, apparent deflections of the meridian, and corresponding apparent deflections in the prime vertical. Appendix C (Table 1), astronomical (telegraphic) longitudes of the oblique arc along the Atlantic; (2) comparison of the register longitudes, apparent deflections in longitude, and corresponding apparent deflections in the prime vertical.
1888	4	471–563	Determinations of latitude and gravity for the Hawaiian Government.—By E. D. Preston, Assistant. (For abstract of contents see under "Gravity.")
1889	7	199–208	The need of a remeasurement of the Peruvian arc.—By E. D. Preston, Assistant.

GRAVITY.

1876	15	292–337	Measurements of gravity at initial stations in America and Europe.—C. S. Peirce. Stations Geneva, Paris, Berlin, Kew, Hoboken; instruments; diagram; observations of the duration of an oscillation; corrections 1 to 12; correction for rate of timekeeper; Paris meridian clock; diagram; Stand und Gang von Serffert, 1876, April 15–June 16; Kew; comparison of chronometers, diagram; Hoboken; table of instrumental constants; comparison of chronometers; instrumental constants; rates of chronometers graphically represented; diagrams Nos. 31 to 35; correction for arc; tables showing times of reading half amplitudes; Paris, Berlin, Kew; table of decrement of arc from 1° 10′; diminution of arc; decrement of pendulum arc, Hoboken, N. J., times of reaching different amplitudes; tables; diagram 36; reduction to a vacuum; coefficient of expansion; diagrams 37[a], 37[b]; comparison of meters "A" and "49"; correction for wearing of the knife-edges; correction for slip of the knife-edges; correction for shorter length with heavy end up; for flexure of the support; length of the pendulum; on the tenths of millimetres at the ends of the United States Coast Survey pendulum metre, and on the screw revolutions of the Repsold vertical comparator; value of the screw revolutions of the upper microscope; of the lower microscope; results of observations of length; summary of results of comparison of lengths between the standard metre "49" and others; comparison of Prussian and United States pendulum standards, 1875; concluded length of the pendulum; center of mass; periods of oscillation and values of gravity; diagram; length of seconds pendulum at Geneva; tables of experiments, Paris, 1876, Berlin, Kew, Hoboken, N. J.
1876	15	410	Addendum to Appendix No. 15. Tables showing the modes of reducing the experiments.
1881	14	359–441	On the flexure of pendulum supports.—By C. S. Peirce, Assistant.
1881	15	442–456	On the deduction of the ellipticity of the earth, from pendulum experiments.—By C. S. Peirce, Assistant.
1881	16	457–460	On a method of observing the coincidence of vibrations of two pendulums.—By C. S. Peirce, Assistant.
1881	17	461–463	On the value of gravity at Paris.—By C. S. Peirce, Assistant.
1882	22	503–516	Report of a conference on gravity determinations held at Washington, D. C., in May, 1882.

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GEODESY—Continued.

GRAVITY—Continued.

Year.	Appendix.	Pages.	Subject and author.
1883	17	379–381	Determinations of gravity and other observations made in connection with the Solar Eclipse Expedition, May, 1883, to Caroline Island. A report by E. D. Preston.
1883	19	473–487	Determinations of gravity at Allegheny, Ebensburg, and York, Pa.—By C. S. Peirce, Assistant.
1884	14	439–473	Determinations of gravity with the Kater pendulums at Auckland, New Zealand; Sydney, New South Wales; Singapore, British India; Tokio, Japan; San Francisco, Cal.; and Washington, D. C.—By Edwin Smith, Assistant.
1884	15	475–482	On the use of the noddy for measuring the amplitude of swaying in a pendulum support.—By C. S. Peirce, Assistant.
1884	16	483–485	Note on the effect of the flexure of a pendulum upon its period of oscillation.—By C. S. Peirce, Assistant.
1885	16	509–510	On the influence of a noddy on the period of a pendulum.—By C. S. Peirce, Assistant.
1885	17	511, 512	On the effect of unequal temperature upon a reversible pendulum.—By C. S. Peirce, Assistant.
1888	14	471–563	Determinations of latitude and gravity for the Hawaiian Government.—By E. D. Preston, Assistant (22 illustrations). Letter of E. D. Preston to Superintendent Coast and Geodetic Survey, transmitting report of work for Hawaiian Government; plate showing crater of Haleakala; note on Hawaiian pronunciation; report; instruments; brief account of journey and work accomplished; plate, "Resting at 'Ana Moe Haole' (9,300 feet elevation) Edge of Crater;" triangulation; plate, "End of Cart Road (5,500 feet elevation), Slope of Haleakala;" plate, "Gravity and Latitude Station, Pakaoao," Island of Maui, etc.; plate, "Trail from Pakaoao to Kaupo Gap;" connections between the trigonometrical and astronomical stations, and geodetic latitudes of the latter (with sketch of triangulation); plate, "meridian telescope;" sketch of triangulation, showing the connection between latitude and gravity stations on the Island of Maui; latitude; inclination of micrometer thread; micrometer; level; discussion of the results; summary of results; observations and reductions for Honolulu; list of star catalogues consulted; mean places of Hawaiian latitude stars; gravity; description of stations; methods of observation; methods of reduction; sketch of Island of Maui, showing contour lines and compartments; results of pendulum observations on Maui; density of the surface rock; reduction of the time observations; plate, "Relative Weights depending on Star's Declination;" plate, "Pendulum Head No. 3;" plate, "Pendulum Stand;" general chart of Caroline Islands, showing gravity station of 1883; observations of 1883; description of stations; length of pendulums and position of center of mass; plate, "Gravity and Latitude Station, Lahaina, Maui;" plate, "Transit No. 2;" plate, "Pendulum Stand, 1887;" plate, "Repsold Vertical Comparator, with Pendulum No. 4 and 'Y and M No. 1,' in position;" plate, "Pendulum No. 3 (Peirce);" plate, "Chronograph;" plate, "Variations of Clock Rates;" diagram showing relative times of star observations and pendulum swings; difference between pendulums No. 3 and No. 4; instrumental constants and chronometer corrections; star residuals; pendulum observations; reduction to standard temperature and pressure; periods of oscillation at 29·554 inches of reduced barometer at Washington, and at 15° centigrade.
1889	....	137–142	Bulletin No. 11.—Determinations of latitude and gravity for the Hawaiian Government—By E. D. Preston, Assistant (4 illustrations). Introductory remarks; relative gravity determinations; gravity results (with diagram); latitude determinations; geodetic connections and conclusions; map of Hawaiian Islands, showing the primary triangulation, latitude, and gravity stations; sketch of Island of Maui, showing contour lines and compartments; sketch of triangulation, showing connection between latitude and gravity stations on the Island of Maui. [This Bulletin was published as an abstract in advance of Appendix 14, 1888, the full Report not having been printed until January, 1891.]

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GRAVITY—Continued.

Year.	Appendix.	Pages.	Subject and author.
1890	12	625–684	Results of observations made to determine gravity and the magnetic elements at stations on the west coast of Africa and on some islands in the North and South Atlantic, 1889-90.—By E. D. Preston, Assistant (11 illustrations).

GEOGRAPHICAL POSITIONS AND PROJECTIONS—TOPOGRAPHIC AND HYDROGRAPHIC SHEETS.

1851	12	162–442	List of geographical positions determined by the Coast Survey. Sections; method of triangulation and verification; average error; assumed size and form of the globe; station errors; checking of geodetic longitudes by telegraph; longitude of Cambridge from Greenwich; explanation of tables; list.—[Errata, 168, 169, 218, 304, 324, 372, 374, 375, 378: 1851, p. viii; Errata, 163, 169, 189, 190, 191, 194, 217, 218, 220, 258, 271, 276, 286, 324, 360, 372, 374, 375, 378, 400, 402, 404, 409, 416, 425, 480: 1853, p. 181; Errata, 185, 252: 1854, p. xii; Errata, 192, 225, 340, 341, 342, 344, 346, 411: 1855, p. xviii.]
1853	7	14–42	List of geographical positions.—[Errata, 15, 16, *et seq.*, 17, 20, 28, 29, 31, 32, 33, 34, 36, 42: 1854, p. xii; Errata, 19, 20: 1855, p. xviii.]
1853	39	96–163	Tables for projecting maps, with notes on map projections.—C. A. Schott and E. B. Hunt. Map projections classified and defined; Bonne's or modified Flamstead's projection; the polyconic, its properties and varieties; formulas used for the computation of projection tables in use at the Coast Survey Office; graphic construction of polyconic projections, Coast Survey methods; rectangular polyconic method; Table I, relation between the measures of length used in different countries; II, for converting (A) metres into statute miles; (B) statute miles into metres; (C) metres into yards; (D) yards into metres; (E) yards into miles; III, length of a degree of the meridian in nautical and statute miles for each fifth degree of latitude between 20° and 50°; IV (A), length of a degree of longitude between the parallels of 17° and 50°, for each degree of latitude, expressed in nautical miles; (B) length of a degree of longitude between the parallels of 17° and 50° for each degree of latitude, expressed in statute miles; V (A), length in metres of 1° of latitude and longitude for each degree of latitude between 17° and 50°; (B) co-ordinates of curvature for each degree of longitude from 1° to 35°, between latitudes 17° and 50°; VI, projection tables, giving latitude and longitude arcs, and co-ordinates of curvature, from latitude 24° to 50°.—[Errata, 96, 97, 98, 102, 134: 1853, p. 182; Errata, 101, 113, 114, 115, 116, 130, 159: 1854, p. xii; Errata, 132, 137: 1866, p. xx.]
1855	8	119–148	List of geographical positions.—[Errata, 138–140: 1856, p. xx.]
1856	58	296–307	Projection tables.—J. E. Hilgard. Tables applicable to the projection of maps of large extent and minimum distortion in represented area; method; earth's dimensions; Table I, of co-ordinates for projecting the points of intersection of meridians and parallels; II, length, in metres, of one degree of latitude and longitude from latitude 20° to 54°; values of the corresponding radii of the developed parallel, and angles at each pole for 10° of longitude; III, tables for converting measures (A) of metres into statute miles; (B) of statute miles into metres; (C) of metres into yards; (D) of yards into metres; (E) of yards into miles; IV, length of a degree of the meridian in nautical and statute miles for each fifth degree of latitude between 20° and 50°; V, length of a degree of longitude for each degree of latitude from 19° to 54°, expressed in nautical and statute miles; VI, radii and polyconic development of a sphere with radius = 1.
1857	23–24	223–264	List of topographic and hydrographic sheets, showing their titles, dates, scales, and registered numbers, as filed in the office.
1857	25	264–301	List of geographical positions.
1859	18	212–214	Topographic sheets.
1859	19	215–216	Hydrographic sheets.

A subject-index to the professional papers contained in the annual reports, etc.—Continued.

GEODESY—Continued.

GEOGRAPHICAL POSITIONS AND PROJECTIONS—TOPOGRAPHIC AND HYDROGRAPHIC SHEETS—Continued.

Year.	Appendix.	Pages.	Subject and author.
1859	20	216–277	List of geographical positions.
1859	33	328–358	Projection tables for maps of large extent.—J. E. Hilgard. Table I, length in metres of 1° of latitude and longitude, values of the corresponding radii of the developed parallel, and angles at each pole for 10° of longitude; II, co-ordinates of curvature.
1861	13–14	176–180	List of topographic and hydrographic sheets—Continued.
1862	39	418–420	Part of Appendix 39.—Geographical positions on the Pacific coast, United States.—George Davidson, Assistant.
1863	15–16	143–146	List of topographic and hydrographic sheets—Continued.
1864	15	144–182	List of geographical positions.
1865	8	50–99	List of topographic and hydrographic sheets—Continued.
1865	9	99–136	List of geographical positions in Sections V, VI, VII, and IX.
1865	10	137	List of geographical positions determined, approximately, in West Virginia, Kentucky, Tennessee, Alabama, Mississippi, and Missouri.
1865	20	176–186	Projection tables for a map of North America. Diagram; table of lengths, in metres, of 5° of latitude on the straight meridian; table of the radii of the parallels, and 5° of longitude on each parallel; I, table of co-ordinates, latitude 5° to 85°; II, co-ordinates of curvature, latitude 55° to 89°; III, length, in metres, of 1° of latitude and longitude 55° to 89°.
1867	18A	265–274	List of topographic and hydrographic sheets of Alaska, by Russian authority.
1868	13	171–242	List of geographical positions determined by the Coast Survey.
1871	5	84–92	List of original topographic and hydrographic sheets registered in the archives of the U. S. Coast Survey from January 1, 1866, to December 31, 1871.
1873	6–7	82–93	List of original topographic and hydrographic sheets registered in the archives of the Coast Survey from June, 1865, to January, 1873.
1874	6	62–65	Geographical positions of prominent places in the United States.
1874	11	134	Additional geographical positions determined astronomically by the Coast Survey on and near the western coast.
1875	7	89–114	Original topographic sheets registered in the archives of the Coast Survey from January, 1834, to July, 1875 (No. 1 to 1378, inclusive).
1875	8	115–138	List of hydrographic sheets, geographically arranged, registered in the archives of the Coast Survey from January, 1835, to July, 1875 (Nos. 1 to 1244, inclusive).
1877	15	191–192	A quincuncial projection of the sphere.—C. S. Peirce. Tables I, II, of rectangular co-ordinates. (Diagram.)
1880	15	287–296	Comparison of the relative value of the polyconic projection used in the Coast and Geodetic Survey, with some other projections.—C. A. Schott. (Six plates and a chart.) Map projections classified and defined; three groups; first group—the square projection, the rectangular projection, the rectangular equal-surface projection, Cassini's projection, projection with converging meridians, projection by development of an intersecting cylinder, Mercator's projection; second group—Flamsteed's projection, De Lorgna's, Babinet's equal-surface projection, De l'Isle's conic projection, the simple conic projection, Murdoch's projection; third group—Lambert's projection, Bonne's, the polyconic; remarks on the history of Coast Survey projections; formulæ for computation: (1) For an arc of a great circle of the sphere; (2) for the rhumb-line on Mercator's projection; (3) for the straight line on Bonne's projection; (4) for the straight line on the polyconic projection; resulting distances, in nautical miles; resulting azimuths.

A subject-index to the professional papers contained in the annual reports, etc.—Continued.

GEODESY—Continued.

GEOGRAPHICAL POSITIONS AND PROJECTIONS—TOPOGRAPHIC AND HYDROGRAPHIC SHEETS—Continued.

Year.	Appendix.	Pages.	Subject and author.
1884	6	135–321	Tables for the projection of maps, based upon a polyconic development of the Clarke spheroid, and computed from the equator to the pole. History of the projection tables of the survey; the Clarke spheroid; formulæ used in establishing tables; arrangement and explanation of the tables; graphic construction of polyconic projections for limited areas; conversion tables; lengths of degrees of the meridian; arcs of the parallel in metres; meridional arcs; coördinates of curvature.
1885	8	285–439	Geographical positions of trigonometrical points in the States of Massachusetts and Rhode Island, determined by the U. S. Coast and Geodetic Survey between the years 1835 and 1885, and including those determined by the Borden survey in the years 1832 to 1838.—By Charles A. Schott, Assistant. Introduction and explanation of the table of positions; number of stations and location; other statistical matter; observers and years of observation; accuracy of the work; index of stations in Massachusetts; table of geographical positions determined in the State of Massachusetts, and connection with stations in the surrounding States; triangulations of 1832-1885. [Illustrations 25-26.]
1888	8	313–403	Geographical positions of trigonometrical points in the State of Connecticut, determined by the U. S. Coast and Geodetic Survey between the years 1833 and 1886. Introduction and explanation of the tabular results by Charles A. Schott, Assistant. [1 illustration.] Introductory remarks and explanation of data and results; standard geodetic data of the Survey; the unit of length; the geodetic surface of reference; the standard latitude; the standard longitude; the standard azimuth; elevations of stations above sea level not yet available; descriptions of stations; positions of stations and connecting lines shown on map; reduction of observations; explanation of method used in computation; table of logarithmic factors for the computation of geodetic positions, between latitudes 40° 55′ and 42° 55′; position computation, form for direct computation; position computation, form for inverse solution; length of arc of one minute in meridian and in parallel; effect of earth's curvature; positions arranged in geographical groups; observers and years of observation; computers engaged in work; metric conversion tables; errata in Appendix 8, 1885; index of stations in Connecticut; tabular statements of geographical positions; primary stations; subordinate, primary, and secondary stations; Rhode Island State line to Thames River; Thames River; Thames River to Connecticut River; Connecticut River; Connecticut River to Housatonic River; Housatonic River to New York State line.

GEOGRAPHICAL EXPLORATIONS.

Year.	Appendix.	Pages.	Subject and author.
1855	64	374–375	Abstract of a complete historical account of the progress of discovery on the western coast of the United States from the earliest period; compiled, under the direction of the Superintendent, by Dr. J. G. Kohl.
1855	65	376–398	Blake's Geological Report, western coast.—W. P. Blake. Observations on the physical geography and geology of the coast of California, from Bodega Bay to San Diego; physical geography of the mountain ranges adjoining the coast; geology of the principal bays and ports from Point Reyes to San Diego.—[Errata, pp. 379, 380, 382, 387, 388, 392, 394, 395, 396; 1857, p. xviii.]
1856	65	319–322	Annals of discovery on the Atlantic coast.—J. G. Kohl. Abstract of a history of the progress of discovery on the Atlantic coast of the United States.
1856	66	322–324	Annals of discovery, Gulf of Mexico.—J. G. Kohl. Abstract of a memoir on the discovery and geographical development of the shores of the Gulf of Mexico within the limits of the United States.
1857	52	414–433	Western coast annals of maritime discovery and exploration.—J. G. Kohl. Report of the method and scope of a memoir on.
1860	41	399-402	Labrador expedition.—Lieut. A. Murray, U. S. N. Report of a voyage of the steamer *Bibb*. [One illustration.]

A subject-index to the professional papers contained in the annual reports, etc.—Continued.

GEODESY—Continued.

GEOGRAPHICAL EXPLORATIONS—Continued.

Year.	Appendix.	Pages.	Subject and author.
1867	18	187–329	Alaska Territory; coast features and resources.—G. Davidson. Directory of the coast, 226–264; list of geographical positions, 265–274; aids to navigation, 274–280. [Sketches 21 to 23.] [Errata, 289, 22 from bottom, *read* Escholtz Bay.]
	E	281–290	Alaska Territory, geology of.—Th. A. Blake. *Ibid.*
	F	290–292	Zoölogy of Alaska Territory.—W. G. W. Harford.
	G	293–298	Vocabularies of the Kodiac, Unalashka, Kenai, and Sitka languages.
	H	299–317	Alaska Territory, meteorology of.—A. Kellog.
	L	318–324	Botany of Alaska Territory.—A. Kellog.
	N	325–329	Vocabulary, Alaskan.
1868	14	243–259	Geographical names on the coast of Maine.—Ed. Ballard.
1868	15	260–277	Condensed account of M. Hellert's explorations on the Isthmus of Panama, including his special explorations on the Isthmus of Darien, with suggestions for conducting a future survey.—G. Davidson. Explorations; plan for exploration of the River Darien; outfit and duties of engineers; instrumental outfit; use of the heliotrope for communicating messages; form of record of levelings, courses and distances; rod for leveling, distance, and station mark for courses; to pack, unpack, and refill steel barometer; methods of ascertaining the discharge of water in any stream.
1873	11	111–112	Geographical and hydrographical explorations on the coast of Alaska.—W. H. Dall. Islands of Attu, Bouldyr, Kyska, Amchitka, Adakh, Atka, Amlia, Four Craters, Agashagok, Unalashka, Sannakh Reefs, Popoff Strait, current observations, azimuths, positions, and magnetic declinations, tables 1 to 16; thermometer, mean for 1873; surface of sea water; five fathoms below surface; current observations made on board the *Yukon* during the voyage from San Francisco to Unalashka, May, 1873; heights of mountains determined in 1873. [Sketch No. 17.]
1874	....	22	United States Coast Survey. Report on the Nicaragua route for an interoceanic ship canal, with a review of other proposed routes; made by Maximilian von Sonnenstern to the minister of public works of Nicaragua. (One illustration. Translated for the United States Coast Survey. Separately published.)
1875	10	157–188	Report on Mount Saint Elias, etc., Alaska.—W. H. Dall. I. Historical notes; tabular results of heights, latitudes, and longitudes; general considerations. [Sketches 22, 23.] II. Discussion of data; reduction of observations, made in 1874, to determine the heights of Mounts Saint Elias, Cook, Crillon, Fairweather, and Vancouver; details of computations.
1880	18	346–411	Landfall of Columbus.—G. V. Fox. An attempt to solve the problem of the first landing place of Columbus in the New World. Introduction; narrative and discussion; the track of Navarrete; of Varnhagen; of Washington Irving; of Capt. Becher; according to G. V. Fox; conclusion; summary. Appendix A, p. 401; age of Columbus. Appendix B, p. 401; mile and league of Columbus. Appendix C, p. 403; variation of the compass in 1492. Appendix D, p. 405; the log of Columbus across the Atlantic Ocean, 1492. Appendix E, p. 408; the vessels of Columbus. [Sketch No. 83.]
1884	19	495–617	History of discovery and exploration on the coasts of the United States.—By J. G. Kohl, PH. D. Prefatory note; abstract of contents; discovery and exploration on the Atlantic coast; the Northmen; Sebastian Cabot, 1497; Ponce de Leon, 1512; Lucas Vasquez de Ayllon, 1520–1525; John de Verrazano, 1524; Estevan Gomez, 1525; English voyage, 1527; Spanish expeditions, 1524–1543; Capt. Jean Ribout; Sir John Hawkins, 1565; Florida, 1565–1574; Sir Walter Raleigh; Capt. John White, 1587–1590; Coast of New England, 1602–1605; Gosnold and Gilbert, 1602; Martin Pring, 1603; Bartholomew Gilbert, 1603; Sieur de Monts and Champlain, 1605; Capt. George Weymouth, 1605; Capt. Christopher Newport, 1606; Capt. John Smith, 1608; Capt. Popham and Raleigh, 1607; Capt. Samuel Argall, 1613; Capt. John Smith, 1614; Henry Hudson, 1609; David Pietersz de Vries, 1632; table of maps of the Atlantic coast of North America, or parts thereof, published between 1500–1770;

A subject-index to the professional papers contained in the annual reports, etc.—Continued.

GEODESY—Continued.

GEOGRAPHICAL EXPLORATIONS—Continued.

Year.	Appendix.	Pages.	Subject and author.
			discovery and exploration of the Gulf of Mexico—abstract of contents; Columbus, 1492-1502; Sebastian Cabot, 1497; Juan Diaz de Solis and Vincente Yanez Pinzon, 1506; Sebastian de Ocampo, 1508; Juan Ponce de Leon, 1512; Velasquez, 1511–1514; Diego Miruelo, 1516; Cordova; Grijalva and Alaminos, 1518; Fernando Cortez, 1519; Don Alonzo Alvarez Pineda, 1519; Narvaez, 1520; Pineda and Camargo, 1520; Francisco de Garai, 1523; Narvaez, 1527–1536; De Soto, 1539; Diego Maldonado, 1540; Andres de Ocampo, 1543; Guido de Las Bazares, 1558: French and English adventurers, 1555–'67; Menendez, 1573; New Mexico, 1581–'83; Robert de la Salle, 1682; Juan Enriquez Barroto, 1685; Iberville, 1698–'99; St. Joseph's Bay, 1718; Galveston Bay, 1721; Charlevoix, 1722: titles and copies of maps illustrating Dr. Kohl's History of the Discovery and Exploration of the Gulf of Mexico; discovery and exploration of the Pacific coast of the United States, abstract of contents—introduction, 1532–1579; California, 1532–'34; California, 1535–'36; California, 1539–'40; Sir Francis Drake, 1579; Francisco Gali and Jayme Juan, 1584; Sebastian Rodriguez Cermenon, 1595; Sebastian Vizcaino, 1596; New Mexico and California, 1582–1717; Juan Ugarte, 1722, 1732, 1746, 1766; Russian expeditions; French expeditions, 1769; Franciscans and Vancouver, 1769–'92; Missions, 1769; Don Juan Bautista Anza, 1774; Sonora-San Diego, 1775; Northwestern coast, 1775; San Francisco Bay, 1775; Santa Clara Mission, 1776, 1779; Capt. James Cook, 1778; La Pérouse, 1786, 1785–1787; Capt. John Meares, 1788: Strait of Fuca, 1789; Don Manuel Quimper, 1790; Malaspina, 1791; Marchand, 1791; Vancouver, 1792–'95; Galiano and Valdez, 1792 Caamaño, 1792; Capt. W. R. Broughton, 1795–'98; Lewis and Clarke, 1804–'06; Russian expeditions, 1803–'06; Fur companies, 1806–'21; Russian settlements, 1812–'41; Missionary travels; Capt. F. W. Beechy, 1827; Sir Edward Belcher, 1836–'42; French explorations, 1820–'42; United States expeditions, 1820–'47; United States exploring expeditions, 1838–'41; Oregon and California, 1842–'46; Maj. W. H. Emory, U. S. Corps Topographical Engineers, 1846–'47; titles of copies of maps of the Pacific coast of North America, or parts thereof.
1886	7	155–253	An examination of some of the early voyages of discovery and exploration on the northwest coast of America from 1539 to 1603.—By George Davidson, A. M., PH. D., Assistant. Introduction, prefatory remarks: efforts to reconcile many of the discrepancies of the old Spanish, English, American, and French navigators; indomitable courage and perseverance of the old Spanish navigators; many of the positions of Ulloa, Cabrillo, Ferrelo, Drake, and Vizcaino can now be located; effort to follow the navigators day by day; some of the authorities cited; origin of name California; what it designated; principal work consulted; description of localities by the different navigators, Ferrelo, Cabrillo, Ulloa, and Vizcaino, with notes by Davidson, placed in four parallel columns; table of the landfalls of Cabrillo (C.) and Ferrelo (F.), with their names by Ulloa (U.), Drake (D.), and Vizcaino (V.), and the present names and latitudes. Index to Appendix 7, 1886. Prefatory note; authorities and publications consulted or referred to; discoverers and explorers; harbors (ports) and anchorages, bays, channels, coves, gulfs, lagoons, straits; headlands; capes, points, bluffs; islands, reefs, and rocks; mountains and mountain ranges (Sierras), table-lands (mesas); rivers, and streams; settlements; Indian villages (Pueblos); miscellaneous notices. [Illustration 18.]
1888	....	3–6	Bulletin No. 2. Notes on Alaska from recent surveys.
1890	19	759–774	Notes on an original manuscript chart of Bering's expedition of 1725–'30, and on an original manuscript chart of his second expedition; together with a summary of a journal of the first expedition, kept by Peter Chaplin, and now first rendered into English from Bergh's Russian version.—By William H. Dall. (Two illustrations.)
1890	20	775–777	On an early chart of Long Island Sound.—By Capt. C. H. Townshend.

A subject-index to the professional papers contained in the annual reports, etc.—Continued

HYPSOMETRY.

SPIRIT LEVELING.

Year.	Appendix.	Pages.	Subject and author.
1854	34	95-103	Measurement of heights.—T. J. Cram. Experimental comparison of the methods of measuring heights by leveling, by vertical angles, by the barometer, and by the boiling-point apparatus. [Errata, 102; 1855, p. XIX.]
1860	38	397	Table of heights for the use of topographers.—C. A. Schott. Height in feet corresponding to a given angle of elevation and a given distance in metres, for use in the construction of contour lines by plane tables.
1870	7	75-76	Report on the leveling operations between Keyport, on Raritan Bay, and Gloucester, on the Delaware River, to determine the heights above mean tide of the primary stations Beacon Hill, Disboro, Stony Hill, Mount Holly, and Pine Hill.—R. D. Cutts. Heights above mean tide determined by the spirit level, p. 75; tidal stations, p. 75; instruments, p. 75; tidal observations and records, p. 76.
1870	9	90-91	List of heights, above the half-tide level of the ocean, of trigonometrical stations determined by the U. S. Coast Survey.
1871	11	154-170	Comparison of the methods of determining heights by means of leveling, vertical angles, and barometric measures, from observations at Bodega Head and Ross Mountain, California.—George Davidson, C. A. Schott. (1) Result of the leveling operations. (2) Results of hourly observations of reciprocal and simultaneous zenith distances for difference of heights of the two stations; Tables 1 to 6, zenith distances, atmospheric pressure, etc.; reduction of zenith distances: diagrams. (3) Results of hourly observations of atmospheric pressure for difference of heights of the stations; diagrams.
1879	15	202-208	Precise leveling.—O. H. Tittmann. Instruments and methods used in the Coast and Geodetic Survey (Sketch No. 53); description of level; rod and target; adjustments (Figs. 1 to 6); verification and adjustments of the rods; methods—(1) simultaneous double leveling in one direction; (2) leveling in opposite directions; method of observing (*a, b, c, d*); river crossing; bench marks; degree of precision; records and computations; curvature and refraction; temperature correction; table of curvature and refraction; form of record; form of computation; form of abstract of results.
1879	16	212-213	Refraction on lines passing near a surface of water, from observations made at different elevations across the Potomac River.—Andrew Braid. Summary of results.
1880	11	135-144	Geodetic leveling on the Mississippi River.—Andrew Braid. Bench marks; instrument; rods; method of observing; specimen of record; probable and mean error; abstract of results; sketches 45, 46, 47.
1882	11	517-556	Results of the transcontinental line of geodetic spirit leveling near the parallel of 39°. First part from Sandy Hook, N. J., to St. Louis, Mo.—Field work executed by Andrew Braid, Assistant (with map). Reduction, by Charles A. Schott, Assistant. Prefatory remarks; determination of the mean tidal level at Sandy Hook; instrumental constants; probable error of results from geodetic spirit leveling; table of results from Sandy Hook, N. J., to Hagerstown, Md.; descriptions of primary and secondary bench marks between Sandy Hook, N. J., and Hagerstown, Md.; table of results from Hagerstown, Md., to Grafton, W. Va.; description of primary and secondary bench marks between Hagerstown, Md., and Grafton, W. Va.; table of results from Grafton, W. Va., to Athens, Ohio: description of primary and secondary bench marks between Grafton, W. Va., and Athens, Ohio; table of results from Athens, Ohio, to Mitchell, Ind.; description of primary and secondary bench marks from Athens, Ohio, to Mitchell, Ind.; table of results from Mitchell, Ind., to St. Louis, Mo.; description of primary and secondary bench marks between Mitchell, Ind., and St. Louis, Mo.; sketch showing the position of the principal bench marks from Sandy Hook, N. J., to St. Louis, Mo. [Illustration 32½.]
1887	9	185-205	Heights from spirit levelings of precision between Mobile, Ala., and Carrollton (New Orleans), La.—Executed by J. B. Weir, Assistant, in 1885-'86. Reported by Charles A. Schott, Assistant. Route of levels, date of leveling, observer, instruments, and instrumental constants; comparison of length and divisions of rods with standard on Saxton's dividing and comparing machine; method of observing;

A subject-index to the professional papers contained in the annual reports, etc.—Continued.

HYPSOMETRY—Continued.

SPIRIT LEVELING—Continued.

Year.	Appendix.	Pages.	Subject and author.
			statistical information; computations; results in three tables. I contains the individual results and the necessary data to enable one to judge of the accuracy of the measures; II shows the resulting heights and probable uncertainties of the principal bench marks between Biloxi and Carrollton above the average Gulf level and a comparison of results from two levelings, *i. e.*, that by the Mississippi River Commission and that by the Coast and Geodetic Survey; III exhibits the resulting heights and probable uncertainties of the line Biloxi to Mobile; description of bench marks.
1887	14	275-300	Report of the results of spirit leveling of precision about New York Bay and vicinity in 1886 and 1887.—Observations by John B. Weir, Assistant, and J. E. McGrath, Subassistant. Discussion by Charles A. Schott, Assistant. Route lines of levels, with map; observers and dates of leveling; instrumental constants; method of observing; computations; resulting elevations; result of geodetic leveling in the vicinity of New York, 1886-'87; main line from Sandy Hook, N. J., to Dobbs Ferry, Hudson River, N. Y.; accuracy of the preceding results for heights; location and description of bench marks in the main line and branches of spirit levels, Sandy Hook to Dobbs Ferry. [Illustration 43.]
1888	10	409-426	Heights from spirit leveling of precision between Mobile, Ala., and Okolona, Miss.—Field work by J. B. Weir, Assistant, and J. E. McGrath, Subassistant, in 1884, 1886, 1887. Reduction by C. A. Schott, Assistant.
1888	11	427-453	Heights from spirit leveling of precision between New Orleans, La., and Arkansas City, Ark.—Field work between New Orleans and Greenville, Miss., by O. H. Tittmann and Andrew Braid, Assistants, and by John B. Weir, Subassistant, in 1879, 1880, and 1881, and between Greenville, Miss., and Arkansas City, Ark., by the Mississippi River Commission, in 1880 and 1881. Reduction by Charles A. Schott, Assistant.
1888	12	455-464	Heights from spirit leveling of precision between Arkansas City, on the Mississippi River, and Little Rock, Ark.—Field work by J. E. McGrath, Subassistant, in 1887-1888. Reduction by Charles A. Schott, Assistant.
1889	15	461-466	Result of spirit leveling between tide water at Annapolis, Md., and the Capitol bench mark at Washington, D. C.—From observations in 1875, by F. W. Perkins, Assistant. Report by C. A. Schott, Assistant.

TRIGONOMETRIC AND BAROMETRIC HEIGHTS.

Year.	Appendix.	Pages.	Subject and author.
1854	34	95-103	Measurement of heights.—T. J. Cram. Experimental comparison of the methods of measuring heights by leveling, by vertical angles, by the barometer, and by the boiling-point apparatus.—[Errata, 102: 1865, p. XIX.
1868	7	124-129	Trigonometrical leveling.—R. D. Cutts. (1) By reciprocal zenith distances; (2) by zenith distances measured at one station; (3) by observed zenith distances of the sea horizon; (4) by observed angles of elevation or depression.
1870	8	77-89	Report on the results of barometrical observations made in connection with the line of spirit leveling, from Raritan Bay to the Delaware River, to determine the heights, etc.—R. D. Cutts. Comparison of instruments and the determination of personal errors, pp. 77-81; the computations, pp. 81-89.
1870	9	90-91	List of heights, above the half-tide level of the ocean, of trigonometrical stations determined by the U. S. Coast Survey.
1871	11	154-170	Comparison of the methods of determining heights by means of leveling, vertical angles, and barometric measures, from observations at Bodega Head and Ross Mountain, California.—George Davidson, C. A. Schott. (1) Result of the leveling operations; (2) results of hourly observations of reciprocal and simultaneous zenith distances for difference of heights of the two stations; tables 1 to 6, zenith distances, atmospheric pressure, etc.; reduction of zenith distances; (3) results of hourly observations of atmospheric pressure for difference of heights of the stations; diagrams.

A subject-index to the professional papers contained in the annual reports, etc.—Continued.

HYPSOMETRY—Continued.

TRIGONOMETRIC AND BAROMETRIC HEIGHTS—Continued.

Year.	Appendix.	Pages.	Subject and author.
1871	12	171–175	Report on the leveling operations between Keyport, on Raritan Bay, and Gloucester, on the Delaware River, to determine the height above mean tide of the primary stations Beacon Hill, Disboro, Stony Hill, Mount Holly, and Pine Hill.—R. D. Cutts. Tidal stations; instruments; field operations and records; Tables I to V.
1876	16	338–353	Reprint of Appendix 11, Report of 1871.
1876	17	355-367	Observations of atmospheric refraction.—Contribution No. II.—C. A. Schott. Determination of several heights by the spirit level, and measures of refraction by zenith distances; also, observations of the barometer at Ragged Mountain, Maine, by F. W. Perkins. (A) Results of the operations by spirit level executed near the entrance of Penobscot Bay in 1874; (B) results of observations of zenith distances at Ragged Mountain for atmospheric refraction; tables; diagram; meteorological observations; (C) meteorological observations at Ragged Mountain, at Mount Desert, and at White Head Light; two short simultaneous sets; resulting differences of height.
1876	18	368–387	Atmospheric refraction and adjustment of hypsometric measures.—Contribution No. III.—C. A. Schott. Determination of the coefficient of refraction from zenith distances observed in northern Georgia, by Assistants C. O. Boutelle and F. P. Webber, in 1873 and 1874, and adjustment of difference of heights by the method of least squares: (1) results of atmospheric refraction observed at stations in northern Georgia in 1873–1874; tabulated zenith distances; determination of the coefficient of refraction from observed zenith distances; resulting values for coefficient of refraction; (2) computation of heights of stations from measured difference of height, with application of the method of least squares; heights above mean sea level; adjustment of results; formation of conditional equations; equations of correlatives; normal equations; probable error of resulting heights; additional remarks and examples for adjustment of heights measured under conditions different from those obtained above; table of log. M and log. N; table of logarithms of radius of curvature to the earth's surface for various latitudes and azimuths, based upon Clarke's ellipsoid of rotation (1866) and for the metric unit.
1876	19	388-390	Hypsometric formulæ, based upon thermodynamic principles.—C. A. Schott.
1881	10	225–268	Meteorological researches, Part III—Barometric hypsometry and reduction of the barometer to sea level, by William Ferrel. Chapter I, the theory of barometric hypsometry; Chapter II, practical applications of the theory; Chapter III, reduction of the barometer to the sea level; hypsometrical tables; errata in Part II; diagram.—[Illustration 38.]
1883	12	289-321	Results of observations for atmospheric refraction on the line Mount Diablo to Martinez, California, in connection with hypsometric measures by spirit level, the vertical circle, and barometer, made in March and April, 1880, by George Davidson, Assistant. Reported by Charles A. Schott, Assistant. Introduction; observations of double zenith distances for the measure of refraction and of differences of height. Table I, Zenith distances of Martinez east, observed at Mount Diablo, and reduced to station marks at both stations, March and April, 1880. Table II, Zenith distances of Mount Diablo, observed at Martinez east, and reduced to station marks at both stations, March and April, 1880; combination of the preceding tabular zenith distances to obtain a homogeneous series of hourly mean values. Table III, Observations at Mount Diablo, California, March and April, 1880. Table IV, Observations at Martinez east, California. Table V, Diurnal variation in angle of refraction, in the coefficient of refraction, and in error of computed differences of height. Table VI, Atmospheric pressure observed at Mount Diablo, March and April, 1880. Table VII, Atmospheric pressure observed at Martinez east, March and April, 1880. Table VIII, Atmospheric temperature observed at Mount Diablo, March and April, 1880. Table IX, Atmospheric temperature observed at Martinez east, March and April, 1880. Table X, Observations of atmospheric humidity at Mount Diablo, March and April, 1880. Table XI, Observations of humidity at Martinez east, March and April, 1880. Table XII, Observations at Mount Diablo, California, March and April, 1880. Table XIII, Observations at Martinez east. Table XIV, Observations at Mount Diablo, Cali-

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HYPSOMETRY—Continued.

TRIGONOMETRIC AND BAROMETRIC HEIGHTS—Continued.

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			fornia, March and April, 1880. Table XV, Observations at Martinez east, California. Table XVI, Observations at Mount Diablo, California, March and April, 1880. Table XVII, Observations at Martinez east, California; barometric differences of height; Dr. Jordan's formula. Table XVIII, Values of $\triangle h$, computed from Jordan and Rühlmann's formulæ, with apparent error in mean temperature t. Table XIX, Comparison of Bauernfeind's theory of refraction with observations at Mount Diablo and Martinez east. Table XX, Comparison of Jordan's theory of refraction with observations at Mount Diablo and Martinez east. Table XXI, Rate of change of temperature with altitude for the stratum of air between Martinez east and Mount Diablo. Table XXI (*b*), Rate of change of temperature with altitude for the stratum of air between Bodega Head and Ross Mountain, California, and comparison of observed and computed temperatures at these stations. Table XXII, Comparison of deduced and observed temperatures of the air at the observing stations Martinez east and Mount Diablo. Table XXIII, Observations of the direction and force of the wind and state of the sky at Martinez east, California, March and April, 1880. Table XXIV, Observations of the direction and force of the wind and state of the sky at Mount Diablo, California, March and April, 1880. Diagram of the hypsometric measures at Mount Diablo and Martinez east, California.
1884	10	391-405	Results of a trigonometral determination of the heights of the stations forming the Davidson quadrilaterals. Observations by George Davidson, assistant, 1876–1882. Discussion by Charles A. Schott, assistant, 1884. Introductory remarks; accommodation of observations to Jordan's formulæ with auxiliary tables; abstract of resulting vertical measures and computations of heights of stations forming the Davidson quadrilaterals, California; specimen of record; specimen of abstract of resulting daily measures of the zenith distance of the same object; abstract of resulting zenith distances and of other data for the computation of heights involved in the Davidson quadrilaterals; resulting differences of heights; estimate of the probable error of the resulting $\triangle h$ and determination of weights for their adjustment; adjustment of the measured differences of heights of stations forming the connection of the Yolo base with the principal triangulation by application of the method of least squares by the process referring to indirect observations, with diagrams; recapitulation of measures.

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TOPOGRAPHY.

1855	21	162, 163	New York City.—Report of F. H. Gerdes, Assistant, on his topographical survey of Manhattan Island.
1855	22	164	Report on topography executed by the party of Assistant S. A. Gilbert on the western and southern sides of Long Island.
1855	23	164, 165	Report on topography executed by the party of Assistant A. M. Harrison on the coast of New Jersey.
1856	48	281, 282	Comparative maps, New York Harbor.—A. Boschke. Method of survey.
1860	38	397	Table of heights for the use of topographers.—C. A. Schott, Assistant. Height in feet corresponding to a given angle of elevation and a given distance in metres, for use in the construction of contour lines by plane tables.
1865	22	203-231	Treatise on the plane table and its use, with diagrams.—A. M. Harrison, Assistant. Description; adjustments; paper; scales; projections for field work; three-point problem; practical modes of determining the position of a fourth point by resection upon three fixed points; Lehmann's method; Netto's method; Bessel's methods; two-point problem; field work: contours; example; table of heights; chain; telemeter; table of reduction of hypothenuse to base; reconnaissance; office work.—[Sketches 30, 31, 32.]

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Year.	Appendix.	Pages.	Subject and author.
1879	11	191	Report on the preparation of standard topographical drawings.—By Edwin Hergesheimer, Assistant. [Illustrations 42 to 49, inclusive.] This paper was afterwards republished as the first part of Appendix No. 11, 1883.
1880	13	172–200	A treatise on the plane table and its use in topographical surveying.—By E. Hergesheimer, Assistant. Description; alidade, new style; old style; adjustments; field work; three-point problem; by construction; by trigonometry; determination of position by resection; Bessel's method by inscribed quadrilateral; by construction of similar triangles; practical modes of determining, from the triangle of error, the position of a fourth point by resection upon three fixed points; Lehmann's method; Netto's method; two-point problem; representation of the terrene; table of heights; example; formula for determining heights by a vertical angle and distance; example; comparison of feet and metres; regular and irregular method of determining curves; adjustment of the new alidade for observation of altitudes; example; distance; stadia; composed of two parts, rod and telescope with vertical arc; focal distance; its relation to the distant object; table for reduction of hypothenuse to base; projection for field sheets.—[Illustrations 49 to 61.]
1881	7	124, 125	Type forms of topography, Columbia River.—By E. Hergesheimer, Assistant. Discussion of the forms of the hills and mountains of the basin of the Columbia River below Wallula, with diagrams.—[Illustration 33.]
1883	14	367, 368	Report on the preparation of standard topographical drawings.—By Edwin Hergesheimer, Assistant. List of drawings which represent various special types of topography, with topographical drawings to be used as guides for inking original plane-table sheets.—[Illustrations, 35 to 50.]

HYDROGRAPHY.*

1852	14	97, 98	Screw-pile signals along Florida reef.—James Totten.
1853	37	93, 94	Aligning reflector or interranger, Hunt's.—E. B. Hunt.
1855	16	157–160	Florida reef screw-pile beacons.—Description of signals.—James Totten.
1855	56	361	Specimen box.—B. F. Sands. Instrument for procuring specimens of bottoms in sounding.—[Sketch 55.]
1855	60	365, 366	Sands's hydrographic signal.—B. F. Sands. Description and drawing of his gas-pipe signal used in the breakers on Dog Island Bar.—[Sketch 54.]
1857	13	150, 151	Method of sweeping.—(See Depths at Hell Gate, etc.)
1857	47	398–401	Sounding apparatus. New method proposed by E. B. Hunt for sounding in moderate depths.
1857	48	401, 402	Experimental soundings made with Hunt's sounding apparatus.—W. G. Temple.
1860	39	398	Sounding apparatus (specimen), Mitchell's, for shallow water.—[Sketch 40.]
1856	18	133–137	Depths in channel entrances of harbors, rivers, ports, and anchorages on the coasts of the United States.
1857	21	178–184	The same.—[Errata, 182, 183; 1857, p. xviii.]
1859	15	168–171	The same.
1862	5	86–92	The same.

* There are a large number of appendices in the earlier reports of the Survey which are properly classified under this heading, but which have only a transient value, since they relate to sailing directions for entering harbors, to the establishment of light-houses, the placing of buoys, etc., and in general to hydrographical conditions existing between thirty and forty years ago.

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SURVEYING—Continued.

HYDROGRAPHY—Continued.

Year.	Appendix.	Pages.	Subject and author.
1874	17	66-71	The same.
1883	7	137-237	A table of depths for the harbors of the coasts of the United States.—Prepared in outline by Commander Edward P. Lull, U. S. N. Expanded and extended by J. S. Bradford, Assistant, and Mr. John W. Parsons. Tides; table of depths, Atlantic coast; table of depths, Gulf coast; table of depths, Pacific coast; table of depths, Pacific and Arctic coasts, Alaska and eastern coast of Asia.
1878	....	50	General instructions in regard to inshore hydrography.
1883	....	1-81	General instructions for hydrographic work—(One pamphlet, octavo, separately printed.)

PHYSICAL HYDROGRAPHY.

TIDES, CURRENTS, WINDS, AND SHORE-LINE CHANGES DUE TO THE ACTION OF THE SEA.

1845	3	41-43	Remarks on the currents in Mississippi Sound and changes in the magnetic variation —F. H. Gerdes.
1846	8	68-70	Tides at the entrance of Mobile Bay.—C. P. Patterson.
1850	8	80-81	Encroachment of the sea on the south side of Long Island.—Prof. A. G. Pendleton.
1850	9	81-82	Progress of Sandy Hook from 1848 to 1850.—H L. Whiting.—[*See* Sketch 8 (B, No. 4, 1851).]
1851	7	127-136	Notes on Cat Island tides.—A. D. Bache. Discussion; table of diurnal and semidiurnal curves.—[Sketch 35 (H, Nos. 2-6).]
1851	8	136-137	Graphical method of representing current observations, as used in the Coast Survey.—A. D. Bache—[Sketch 3 (A, No. 3).]
1851	28	482-484	Beaufort Harbor, North Carolina.—H. L. Whiting. Operative causes ot its physical permanency.—[Sketch 17 (D, No. 5).]
1851	31	488-494	Florida coast reconnoissance.—F. H. Gerdes. (A) Description; (B) survey; (C) tides and currents; (D) railroad across the peninsula; (E) light-houses and buoys; (F) general remarks on Cedar Keys Harbor.—[Sketches 27, 28, and 29.]
1851	50	528-530	San Diego River entrance.—[Sketches 6 and 7.]—(*See* C, statistics; *a*, coast, western.)
1851	56	553-558	Hell Gate Channel.—W. A. Bartlett. Examination of reefs and changes produced by blasting.—[Errata, p. ix.]
1852	8	84	On Pot Rock, Hell Gate.—W. A. Bartlett.
1852	....	12	U. S. Coast Survey. Directions for observations of tides. Printed for the use of the tidal observers from the manuscript instructions, 1852. (Two illustrations.) Gideon & Co., printers.
1852	22	111-122	Discussion of Cat Island tides.—A. D. Bache. Table I, Sketch 1, diurnal and semidiurnal curves deduced from observations, with curves of sines; (A) diurnal wave; heights and times; II, Sketch 2, maximum ordinates of diurnal curve, etc.; III, Sketch 3, effect of sun's declination on height; IV, effect of moon's parallax; V and VI, coefficients; VII, computed diurnal ordinates compared with observations; VIII, Sketch 8, residuals classed by moon's ages; IX, same, corrected by change of cosines; X, difference of diurnal maximum ordinates, from last and from first methods of groups—semidiurnal effect; XI, correction to maximum diurnal ordinate for high-water ordinate; XII to XV, further residual corrections; comparison with hypothesis; (B) semidiurnal curve; XVI, half-monthly inequality in height; XVII, discrepancies between observations and formula.—[Sketch 25 (H, Nos. 5-9).]—[Errata, pp. 115, 119, 121; 1853, p. 182.]

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PHYSICAL HYDROGRAPHY—Continued.

TIDES, CURRENTS, WINDS, AND SHORE-LINE CHANGES DUE TO THE ACTION OF THE SEA—Continued.

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1853	27	71–76	Notes on tides at Key West.—A D. Bache. Table I, half-monthly inequality of tides, one year's observations; II, diurnal inequality, with formula; decomposition of the curves of observation; semidiurnal tides; III, first six months; IV, second six months; V, the whole year; diurnal tides; VI, effect of moon's declination; VII, moon's age; changes of mean level; VIII, height of high water referred to moon's age, first and second months; IX, monthly mean level.—[Sketches 27 (F, No. 4) and 28 (F, No. 5)]
1853	28	77–81	Notes on tides at Rincon Point, Cal.—A. D. Bache.—[Tables I to IV.]—[Sketch 48 (J, No. 7)].
1853	29	81–82	Notes on the tides at San Francisco, Cal —A. D. Bache.
1853	....	....	Sandy Hook changes.—[Sketch 8 (B, No. 3).]
1853	38	94–96	Self-registering tide gauge, Saxton's.—E. B. Hunt.—[Sketch 54.]
1854	....	....	Craven's current indicator.—[Sketch 55.]
1854	14	21–23	Beaufort Harbor, North Carolina.—J. N. Maffit. Its capacity, changes, and improvements.—[Sketch 23.]
1854	29	35–37	Nantucket and Vineyard Sound tides.—H. Mitchell. Method of securing Mitchell's tide gauge; remarks on swells.—[Sketch 57.]
1854	30	37–40	Western coast tidal and magnetic observations.—W. P. Trowbridge.
1854	45	147–152	Cotidal lines, Atlantic.—A. D. Bache. Preliminary determinations of cotidal lines on the Atlantic coast of the United States, from Coast Survey observations. Table I, observations for cotidal hours; II, cotidal hours of ports on the Atlantic coast; III, rate and trend of cotidal lines.—[Sketch 26.]—[Errata, 151; 1855, p. xix.]
1854	46	152–155	Diurnal inequality, western-coast tides.—A. D. Bache. Comparison of the diurnal inequality of the tides at San Diego, San Francisco, and Astoria, with tables.—[Sketch 49.]—[Errata, 153; 1855, p. xix.]
1854	48	161–166	On the currents of Nantucket Shoals.—C. A. Schott. On the currents of Nantucket Shoals, from Coast Survey current observations.—Table I, mean direction; II, maximum velocity; III, groups of luni-current intervals.—[Sketch 13 (A, No. 12).]—[Errata, pp. 165, 166: 1855, p. xix.]
1854	49	166–168	Muskeget Channel and Marthas Vineyard currents.—C. A. Schott. Table showing the currents and rate of current in Muskeget Channel and on the northeast coast of Marthas Vineyard; velocity of current; duration of ebb, flood, and slack water; current-establishments.—[Sketch 14 (A, No. 13); also, 1855, Sketch 6.]—[Errata, pp. 167, 168: 1855, p. xix.]
1854	50	168–179	Tides, Long Island Sound and approaches.—C. A. Schott. Table I, range, or mean rise and fall of tides, to April, 1853; II, corrected or mean establishments, to April, 1853; III, set and maximum rates of ebb and flood streams; IV, luni-current interval for beginning of outgoing streams; eastern part of the Sound, 1846–'47; western part of New York Bay and channel, 1844; New York Harbor, 1844–'45; Hell Gate, 1845; Hell Gate and Throgs Neck, 1846; V, mean duration of slack waters and of respective ebb and flood streams, from the middle (time) of one slack-water period to that of the next; VI, irregularity of luni-current intervals of successive tides.—[Sketch 16 (B, No. 2).]—[Errata, pp. 172, 174: 1855, p. xix.]
1854	52	189–190	Current-bottles. One from Mobile Bay to Mosquito Inlet and one from Cape Florida to Jupiter Inlet.
1854	53	190–191	Seacoast tide-gauge.—H. Mitchell. Description of tide-gauge used at stations on the open seacoast and in situations exposed to strong currents.—[Sketch 57.]—(*See, also,* 35-37.)—[Errata, for Sketch K read Sketch 57.]
1855	23	164–165	Sandy Hook changes.—[*See* New Jersey, etc.]—A. M. Harrison.—[Sketch No. 9.]
1855	24	170–171	Remarks by Mr. Boschke on surveys made at different periods in New York Harbor.

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PHYSICAL HYDROGRAPHY—Continued.

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1855	33	222–223	Nantucket Sound.—H. Mitchell. Tidal observations; interference-phenomena.
1855	50	338–342	Pacific co-tidal lines.—A. D. Bache. Tidal observations.—Table I, tide stations on the western coast of the United States; II, data for co-tidal lines of the Pacific coast of the United States; co-tidal hours; co-tidal groups; III, discussion of the middle group between Cape Mendocino and Point Conception.—Chart of co-tidal lines.—[Sketch 49.]
1855	51	342–346	Earthquake waves, Pacific Ocean.—A. D. Bache. Notice of earthquake waves on the western coast of the United States, December 23 and 25, 1854; computation of ocean depth.—[Sketch 50 (J, No. 9).]—[Errata, pp. 342, 345: 1855, p. xviii.]
1855	52	346–347	Gulf of Mexico tides.—A. D. Bache. Observations and type curves at the several stations, showing their decomposition into diurnal and semidiurnal tides.
1856	34	249–251	Prediction tables.—A. D. Bache. Notes on the progress made in their preparation with reference to tides of Boston Harbor.
1856	35	252–260	Co-tidal lines, Gulf of Mexico.—A. D. Bache. Discussion and preliminary determination.—Table I, diurnal wave; II, stations, etc.; III, diurnal intervals; IV, tide elements of the stations; V, semidiurnal tides; VI, comparison of establishments of diurnal and semidiurnal tides in the Gulf of Mexico.—[Sketches 35 and 36.]
1856	36	260–261	Type curves, Gulf of Mexico. Descriptive references to Sketch No. 38, representing the decomposition of curves of observations.—[Sketch 38.]
1856	37	261–263	Interference tides.—H. Mitchell. On observations made in Nantucket and Marthas Vineyard sounds.
1856	38	263–264	Tidal currents at Sandy Hook.—A. D. Bache. Notes on the causes of northwardly increase of the peninsula.—[Errata, p. 264: 1856, p. xx.]
1856	39	264–266	New York Harbor and dependencies.—H. Mitchell. On tidal and current observations made in New York Harbor, city docks, Newark Bay, and the Kills.
1856	40	266–267	Hudson River.—G. Würdemann. On tidal observations made between Albany and New York City.—[Sketch 6.]
1856	43	271–272	Winds of Albemarle Sound.—L. F. Pourtales. Discussion of their effect upon the tides.—[Sketch 16.]
1856	44	272–276	Winds in the Gulf of Mexico.—A. D. Bache. Discussion relative to the disturbance caused in the intervals of successive tides at several stations on the Gulf coast.—Table I, quantity and direction of wind at Key West, Fla., 1851–'52; II, at Fort Morgan, Ala., 1847–'49; III, at Galveston, Tex.
1856	45	276–278	Winds and tides in Cat Island Harbor.—Results deduced by G. W. Dean, Assistant, from observations made by G. Wurdemann and R. T. Bassett.—[Sketch 39.]
1856	46	279–280	Cards from current-bottles. Picked up on the shore of Loggerhead Key, Fla., and on the North Caicos, Bahamas.
1857	16	152–153	Beaufort Harbor, North Carolina.—C. R. P. Rodgers. Present condition of bar and anchorage.—[Sketches 29 and 30.]
1857	17	153–155	Cape Fear Entrances, North Carolina.—J. N. Maffit. Elements of physical changes wrought.—[Sketch 33; also, 1855, Sketch 16.]
1857	33	342–347	Atlantic coast tides.—Generalization of heights relative to the configuration of the coast.—A. D. Bache. Table I (A), heights of tides on the Atlantic coast of the United States; II (B), on the coast of Cape Breton and New Brunswick.—[Sketch 65.]

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1865	5	45	Entrance to Cape Fear River, North Carolina.—J. S. Bradford. Hydrographic changes.—[Sketch 13.]
1865	11	138	Explanation of diagram of type curves of the tides on the Pacific coast. [Sketch 26.]
1866	6	44–46	Hell Gate tides (East River, N. Y.).—H. Mitchell. Preliminary report on the interference tides of Hell Gate, with directions for reducing the soundings.—Table of relative elevations of tidal planes from observations; tides and currents of Hell Gate, from observations of 1857.
1866	18	113–119	Tidal observations at Cat Island, Gulf of Mexico: Notes of a discussion.—A. D. Bache. (Reprinted from the report for 1851.)—[Sketch 30.]
1853	26	67–70	Tide tables for the use of navigators, with description of bench marks, explanations and examples for use.—A. D. Bache.
1854	51	180–189	Tide tables for the use of navigators.—A. D. Bache.—[Errata, 181, 182, 183, 185: 1855, p. xx.]
1855	53	347–359	Tide tables for the use of navigators.—A. D. Bache.—[Errata, 349, 351, 353, 354, 358: 1857, p. xviii.]
1856	17	120–133	Tide tables for the use of navigators.—A. D. Bache.—[Errata, 130: 1856, p. xx.]
1857	20	157–178	Tide tables for the use of navigators.—A. D. Bache.
1858	43	275–297	Tide tables for the use of navigators.—A. D. Bache.—[Errata, 279: 1859, p. xvi.]
1859	14	136–167	Tide tables for the use of navigators.—A. D. Bache.—[Errata, 145: 1860, p. xx.]
1860	16	131–164	Tide tables for the use of navigators.—A. D. Bache.—[Errata, 161: 1860, p. xx.]
1861	9	98–131	Tide tables for the use of navigators.—A. D. Bache.
1862	8	93–126	Tide tables for the use of navigators.—A. D. Bache.
1863	12	84–117	Tide tables for the use of navigators.—A. D. Bache.
1864	8	58–90	Tide tables for the use of navigators.—A. D. Bache.
1866	7	47–49	Predictions for Eastport, as a specimen.*
1867	12	149–157	Provincetown Harbor, Massachusetts.—Special survey.—H. L. Whiting.
1867	13	158–169	Tides and currents of Hell Gate, N. Y.—H. Mitchell. General scheme of tides and currents: (1) General scheme of tidal interference; observations and results; curves. (2) Tides from stations selected as characteristic for New York Harbor and its approaches, 1857–'58, with diagram; intervals and heights of tides from simultaneous observations, May and June, 1857, arranged according to hour of transit; curves of half-monthly inequalities. (4) Restoration of level between gauges at Hell Gate Ferry and Pot Cove, 1857; diagram. (5) Currents of New York Harbor; general scheme of currents, graphic.
1867	14	170–175	Merrimack River, Massachusetts.—H. Mitchell. Surveys respecting its navigation, with tables.—[Sketch 2.]
1867	15	176–179	Report on soundings made to develop the character of the Strait of Florida between Key West and Havana. By H. Mitchell.
1868	15	51–102	Discussion of the tides in Boston Harbor.—W. Ferrel. The observations and the locality; expression of the disturbing forces; tidal expressions; object and plan of discussion.—Tables I, II, III, and IV, of average normal values; V, the constant or mean tide; the semimonthly inequality; VI, inequality depending upon the moon's

*In 1866 was begun the separate publication of Tide Tables, predicting for one year in advance the tides on the Atlantic and Pacific coasts.

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			mean anomaly; VII, inequality depending upon the moon's longitude; VII *bis*, inequality depending upon the sun's anomaly and longitude; VIII, inequality depending upon the moon's node; IX, inequalities depending upon η_8 and η_9; diurnal tide; recapitulation of results; comparisons with the equilibrium theory; determination of the general constants; comparisons with the dynamic theory; prediction formulas and Tables I–XI; computation of a tidal ephemeris; conclusion; example of the computation of a tidal ephemeris.
1868	6	103–108	Mode of forming a brief tide table for a chart, with example.—R. S. Avery.—[Sketch 29.]
1869	5	75–104	Reclamation of tide lands, and its relation to navigation.—H. Mitchell. (1) General discussion; scour of tidal and river currents; general rule of bar-scouring; parallel works; transverse works; physical history of salt marshes; shingle levees; other natural levees; Peirce's criterion; (2) field work; Green Harbor River; North River; tabular sections of shingle levees; sand beach; section of slueway formed by Minot's gale; general rise; local changes of heights of tide—tables; effect of a dam; general conclusions relative to the projects of reclamation; shore of Nahant; tabular sections; maps and diagrams (in text).
1869	13	233–234	Abstract of a paper read before the National Academy of Sciences, April 16, 1869, on the earthquake wave of August 18, 1868; wave table.—J. E. Hilgard.
1869	15	236–259	Reports concerning Marthas Vineyard and Nantucket.—H. L. Whiting and H. Mitchell. (A) Edgartown Harbor, changes; Vineyard Haven, its character as a port of refuge and its present condition; Table I, exposure of anchorages in Provincetown Harbor; II, in Vineyard Haven; III, in Great Woods Hole; IV, in Tarpaulin Cove; V, in Edgartown Roadstead; VI, in Old Stage Harbor; VII, in New Bedford Harbor and Quick's Hole; VIII, in Plymouth Harbor; IX, in Boston Harbor and Nantasket Roads; X, in Boston Harbor and Hull Bay; XI, in Boston Harbor and Presidents Roads and Georges Roads; XII, in Marblehead Harbor; XIII, at Salem Harbor; XIV, at Gloucester Harbor; XV, in Lower Bay, New York Harbor; XVI, in Upper Bay, New York Harbor; XVII, anchorage room and average exposure in the respective harbors. (B) Surveys of summer, 1871: (1) Physical aspect and peculiarities; (2) Edgartown tides, difference of heights; (3) Nantucket tide table; (4) elements of the field work.
1870	5	66–69	Tabular statement of results of computed tide tables for charts of the western coast of the United States.—R. S. Avery.
1870	6	70–74	Mode of forming brief prediction tide tables.—R. S. Avery.
1870	10	92–97	Description of bench marks at tidal stations.
1870	11	98–99	Extract from a report relative to a method of determining elevations along the course of a tidal river, without the aid of a leveling instrument, by setting up graduated staves at such distances apart that the slacks of the tidal currents extend from one to another.—Rule: The difference in the elevations of the zeros of the gauges is equal to one-half the sum of the differences of their readings at the two slack waters.—Henry Mitchell.
1870	18	180–181	On the probable effect of extended piers in modifying the channel facilities of San Francisco Bay, near Yerba Buena Island.—Henry Mitchell.
1870	20	190–199	On the moon's mass, as deduced from a discussion of the tides of Boston Harbor.—William Ferrel.
1871	6	93–99	Meteorological effects on tides.—William Ferrel. Graphic representation of the relative amounts and direction of the wind for each of the four seasons for Boston.
1871	7	100–108	Meteorological register, St. Paul Island, Alaska, 1870–'71. By Capt. Charles Bryant, special agent Treasury Department.
1871	8	110–133	Harbor of New York, 1873.—Henry Mitchell. Increase of Jersey Flats; diagram A; changes in Buttermilk Channel; changes in the vicinity of Middle Ground Shoal and Gowanus Bay; changes at and near the Sandy Hook entrance; tides and currents; phenomena in the pathway of the Hudson; movement through East

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PHYSICAL HYDROGRAPHY—Continued.

TIDES, CURRENTS, WINDS, AND SHORE-LINE CHANGES DUE TO THE ACTION OF THE SEA—Continued.

Year.	Appendix.	Pages.	Subject and author.
			River; East River and Hudson tidal current compared; relations of East River movements to those over the bar; Tables 1 to 17; diagrams B, C, D.—[Sketches 30, 31, 32.]
1871	9	134–143	Nauset Beach and Monomoy Peninsula.—H. Mitchell. Physical history of the neighborhood of Monomoy (Sketch No. 35); recent movement of Chatham Beach in detail; tables.
1871	10	144–153	Location of harbor lines.—Henry Mitchell. Value of tidal volume; encroachment on the channels; isodynamic lines (Sketch No. 35); example; anchorage and winding room; requisite depths of frontage; length of slips; riparian rights; laws establishing harbor lines.
1872	6	69–72	Field and office work relating to tides.—R. S. Avery.
1872	7	73, 74	Maxima and minima of tides on the coast of New England for 1873.—William Ferrel.
1872	10	177–212	Harbors of Alaska and the tides and currents in their vicinity.—W. H. Dall.—[Sketch No. 18.] Statistics; notes on the North Pacific current: hydrographic notes on Captains Bay and vicinity; meteorology of Unalashka; tides of Iliuliuk; compound tides: semidiurnal tides; tide referred to the lower transits; to the upper transits; semidiurnal tides; tidal current of Unalashka; the Alaska current; its effect on the climate of the Aleutian district; the circular current of Bering Sea; the Shumagin Islands; western; eastern; miscellaneous hydrographic notes; meteorological observations from September, 1871, to October, 1872; current observations; tides of Iliuliuk.
1872	16	257–261	Middle-ground shoal, New York Harbor.—H. Mitchell. Tables of current observations.—[Sketch No. 22.]
1872	17	262–265	Shore-line changes at Edgartown Harbor, Mass.—H. L. Whiting.—[Sketch No. 23.]
1873	8	91–102	Physical survey of Portland Harbor.—H. Mitchell. Correspondence; sections 1 to 10 for velocities of tidal current; diagrams of the ten sections.
1873	9	103–107	Additional report concerning the changes in the neighborhood of Chatham and Monomoy.—H. Mitchell. The real point of interest; corrections of previous paper; results of the last survey, tables, diagrams.
1873	10	108, 109	Changes in the submerged contours off Sandy Hook.—[Tables, diagram.]—Henry Mitchell.
1874	12	135–147	Terminal points of the proposed canals through Nicaragua and the Isthmus of Darien.—H. Mitchell. Greytown; history of the harbor; causes of its decline and final destruction; the work of restoration; obstructions of the lower San Juan; recapitulation; result of foregoing discussion; Urabá mouth of the Atrato; conclusions relative to the improvement of the Urabá; Brito; conclusions; Limon and Chiri Chiri Bays; general exposure.
1874	....	268	Tidal researches.—William Ferrel.—(Four illustrations.)
1874	16	154	Ocean salinometer.—J. E. Hilgard.
1874	....	16	On the air contained in sea water.—By Oscar Jacobsen. Republished for the U. S. Coast Survey from Annals, Ch. and Ph., Vol. 167, 1873.
1875	11	189–193	Recent observations at South Pass Bar, Mississippi River.—[Sketch No. 24; tables.]—H. Mitchell.
1875	12	194–221	Discussion of tides in New York Harbor.—William Ferrel. General plan and immediate object of the discussion; adopted notations; averages deduced from the observations; Tables I to VI; semidiurnal tides, half-monthly inequality; lunar parallactic inequality; mean lunar declinational inequality; lunar nodal inequality; solar declinational and parallactic inequalities; mean sea level; diurnal tide; Table VII; comparison of theory with observation; practical application; directions for computing a tidal ephemeris. Appendix: Tables I to IV, for computing heights and times of high water; example.

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PHYSICAL HYDROGRAPHY—Continued.

TIDES, CURRENTS, WINDS, AND SHORE-LINE CHANGES DUE TO THE ACTION OF THE SEA—Continued.

Year.	Appendix.	Pages.	Subject and author.
1875	18	293–314	Observations on certain harbor and river improvements collected on a voyage from Hongkong, via Suez, to New York.—George Davidson. Nagasaki; Shanghai; Hongkong; Canton; Singapore; Penang; Calcutta; Bombay; Suez and canal; destructive action by passing vessels; current through the canal; saltness of water; tides; breakwater at Port Said; dredging, estimate of cost; Alexandria; Naples; Genoa; Swinemunde; Copenhagen; Kiel; Hamburg; Bremerhafen; Wilhelmshafen; Amsterdam Canal; entrance-locks and sluices; the béton blocks; North Sea Harbor Breakwater; design; method of building; dam at Schellingwonde, eastern extremity of the Amsterdam Canal; difficulties of construction; Cherbourg; docks; breakwater; Brest; docks; Admiralty Pier, Dover; construction; cost; Portland Breakwater; ripraps; description; cost; Holyhead Breakwater; Alderney Breakwater; conclusions; fascinage for breakwater foundations; river improvements.
1875	20	3[illegible]–412	Meteorological researches for the use of the Coast Pilot.—[Sketches 31 to 37.]—William Ferrel. Prefatory note by C. P. Patterson, Superintendent. Part I. On the mechanics and general motion of the atmosphere. Chapter I. General equations of the motions and pressure of the atmosphere.
		[illegible]79	Chapter II. The temperature and pressure of the atmosphere at the earth's surface obtained from observation; Tables I to V; Tables VI to X, of distribution of atmospheric pressure.
		102	Chapter III. The general motion of the atmosphere; Table XI, velocities; Table VII, direction and velocities. [Errata, §§ 8, 9, 13, 15, 42.]
1875	22	800	On tides and tidal action in harbors.—By Prof. J. E. Hilgard. Reprinted from Smithsonian Report for 1874.
1876	8	80–142	Methods of registering tidal observations.—R. S. Avery. Bench-marks; tide-gauges; self-registering tide-gauges; diagrams; how to use three roller gauge; large cylinder gauge; tabulating high and low water; hourly readings; scales of heights; time, precautions.
1876	9	143–146	Changes in the harbor of Plymouth, Mass.—H. Mitchell. [Sketch No. 22.] Champlain (1605); Blaskowitz (1774); general conclusions and remarks.
1876	10	147–185	Physical survey of New York Harbor.—H. Mitchell. Section XXXVI, Table A; positions of origins and termini of sections examined in 1872–'73–'74–'75; transverse curves of velocity, and perimeters; Sections I to XXXVII.
1876	11	186–189	Report concerning the location of a quay or pier line in the vicinity of the United States navy-yard at New York.—Henry Mitchell. Sections VI to VIII.—[Sketch No. 23.]
1876	12	190, 191	Review of the characteristics of South Pass, Mississippi River.—Henry Mitchell.
1877	8	98–103	Alleged changes in the relative elevations of land and sea.—Henry Mitchell. Salt marshes; rocks; Percé Rock; Isle Percé; Green Ledge; Mary Ann Rocks; Bulwark Shoal; Drunken Ledge; Brazil Rock; Jig Rock; Trinity Ledge; Harding's Ledge; Great Ledge.
1877	9	104–107	Apparatus for observing currents.—H. L. Marindin. Description of floats; diagram.
1877	10	108–113	Optical densimeter for ocean water.—J. E. Hilgard, Assistant in charge of office.
1877	14	184–190	Density of the waters of the Chesapeake Bay and its principal estuaries.—Lieut. Frederick Collins, U. S. N., Assistant. Instruments employed; specific gravity; method of working; explanation of tables in the full report.
1878	9	121–175	Physical survey of the Delaware River at Philadelphia.—Henry Mitchell, Assistant. The channel; form of cross-section; section $7\frac{1}{2}$, Southwest Pass, Mississippi River; diagram A; the Delaware; location of the channel; cross-section; diagram B; table; diagram C; tables; tables of transverse curves of velocity; diagram D.

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PHYSICAL HYDROGRAPHY—Continued.

TIDES, CURRENTS, WINDS, AND SHORE-LINE CHANGES DUE TO THE ACTION OF THE SEA—Continued.

Year.	Appendix	Pages.	Subject and author.
1878	10	176-267	Meteorological researches for the use of the Coast Pilot.—William Ferrel. Part II. On cyclones, waterspouts, and tornadoes. Chapter I. The theory of cyclones.
		206	Chapter II. Practical application of the theory and comparison with observation.
		243	Chapter III. Tornadoes, hail storms, and waterspouts.—[Sketches Nos. 33 to 38.]
1878	11	268-304	Tides in Penobscot Bay.—William Ferrel. I, general principles of the harmonic analysis and discussion of tide observations. II, p. 284, analysis of the tides of Pulpit Cove. III, p. 296, comparison of observations with theory. IV, p. 599, practical application.
1879	10	175-190	Physical hydrography of the Gulf of Maine.—H. Mitchell, Assistant. General description; tides and tidal currents; Tables 1 to 7; George's Bank; Tables 8, 9.
1879	13	199	Addendum to a report on a physical survey of the Delaware River.—Henry Mitchell, Assistant.
1880	....	1-221	Deep-sea sounding and dredging. A description of the methods and appliances used on board the Coast and Geodetic Steamer *Blake*.—By C. D. Sigsbee, Lieutenant-Commander U. S. N., Assistant.—(41 plates, 13 wood cuts.)
1880	9	110-125	Comparison of the surveys of Delaware River in front of Philadelphia, 1843 and 1878.—H. L. Marindin, Assistant. Tables 1, 2. Supplement, p. 116; Tables 3 to 10.
1880	10	126-134	Comparison of surveys of Mississippi River in the vicinity of Cubitt's Gap.—H. L. Marindin, Assistant. Tables 1 to 5.—[Sketch No. 44.]
1880	16	297-340	Bering Sea.—W. H. Dall, Assistant. Report on the currents and temperatures, and also those of the adjacent waters; sources of information; surface temperature; tables of temperatures; pack ice; summer temperatures; the Kuro Siwo and its extensions; table of North Pacific Sea temperatures; comparison of sea temperatures from observations by the Challenger, 1873 and 1875; currents of Bering Sea; observations of the Tuscarora and Venus; those of Krusenstern, 1804-1806; notes by whalers and others; table of temperatures; of currents; observations off the coast of Asia; in the Arctic in general; in the vicinity of Point Barrow. SUPPLEMENTARY NOTE.—Additional observations in the Arctic Sea; boundary line between the territory of the United States and Russia; diagram of surface and vertical isotherms; chart of currents.
1881	18	461-469	Report on a new rule for currents in Delaware Bay and River.—By Henry Mitchell, Assistant. Proposed new rule for the currents of Delaware River; currents of Delaware Bay; "Station No. 4," outside of Cape Henlopen—lighthouse bearing nearly west by compass; diagram showing manner of computing middle line; rule; table of currents of Delaware Bay; table of currents of Delaware River; note relative to the lines of high and low water in Delaware Bay and River; progress of tide in Delaware Bay and River.
1882	15	427-432	Comparison of the survey of Delaware River of 1819, between Petty's and Tinicum Islands, with more recent surveys.—By Henry L. Marindin, Assistant. Different cross-sections compared and changes noted.—[Sketches 41, 42, 43.]
1882	16	433-436	Study of the effect of river bends in the Lower Mississippi.—By Henry Mitchell, Assistant. Introductory remarks; inductions; Table I, a comparison of air-line and river distances with mean depths, mean widths, and mean areas in Mississippi River, beginning in latitude 39° 20′ 46″, longitude 89° 24′ 15″, and ending in latitude 30° 06′ 36″, longitude 90° 54′ 47″; supplementary table; Table II, bend effects in the Mississippi River, from 4½ miles below Fort Saint Philip to near Point Houmas, 150¾ miles; inferences; authority for data.—[Sketch 44.]

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PHYSICAL HYDROGRAPHY—Continued.

TIDES, CURRENTS, WINDS, AND SHORE-LINE CHANGES DUE TO THE ACTION OF THE SEA—Continued.

Year.	Appendix.	Pages.	Subject and author.
1882	17	437–450	Discussion of the tides of the Pacific Coast of the United States.—By William Ferrel. Introductory letter; tides of Port Townsend discussed; tides of Astoria discussed; tides of San Diego discussed; determination of the general constants.—[Sketches Nos. 45, 46, 47.]
1883	8	239–245	The estuary of the Delaware.—By Henry Mitchell, Assistant. Introductory remarks; term estuary defined; table of half-tide dimensions of the estuary of the Delaware; diagram representing mean depths, widths, and sectional areas for each nautical mile; table giving progress of the tide in Delaware Bay and River; discussion concerning tide; résumé of data used; estuary of the Delaware; table of widths, areas, and depths.—[Sketch 25.]
1883	9	247–251	Report on the harmonic analysis of the tides at Sandy Hook.—By William Ferrel. Introductory letter; results of the harmonic analysis of the tides at Sandy Hook; this subject discussed.—[Sketch No. 26.]
1883	10	253–272	Description of a maxima and minima tide-predicting machine.—By William Ferrel. Prefatory letter; introduction; mathematical theory of the tide-predicting machine; mechanical solution of the problem; construction of the machine; directions for setting and using; efficiency of the machine; Appendix.—[Sketches Nos. 27, 28, 29, 30, 31.]
1884	12	431–434	Physical hydrography of Delaware River and Bay.—Comparison of recent with former surveys.—By H. L. Marindin, Assistant. Comparison of cross sections; Table No. 1, changes in Delaware River between 1841 and 1881; Table No. 2, changes in Delaware River between 1840 and 1882.—[Sketches No. 22, 23.]
1885	12	487–488	Comparison of traverse sections in the Delaware River between Old Navy Yard and east end of Petty's Island, for the years 1819, 1843, and 1878.—By Henry L. Marindin, Assistant. Explanation of sketches No. 29, 30, 31, 32, 33, 34, giving a comparison of the transverse sections of the Delaware at various points for the years 1819, 1843, 1878.
1885	13	489–493	On the harmonic analysis of the tides at Governor's Island, New York Harbor.—By William Ferrel. Results of the analysis with sketch showing positions of tide gauges at Governor's Island and Sandy Hook; determination of general constants.—[Illustration 35.]
1885	14	495–501	Report on deep sea current work in the Gulf Stream.—By J. E. Pillsbury, Lieut. U. S. N., Assistant. (*See* Gulf Stream explorations.)
1886	8	255–261	A report on Monomoy and its shoals.—By Henry Mitchell, Assistant. Tonnage of the vessels navigating these waters; dangers to navigation; comparison of Capt. Paul Pinkham's survey of 1784 and the U.S. Coast and Geodetic Survey chart of 1885, with a sketch of the two surveys. Also a report concerning the earliest topographical survey of Monomoy, with sketch.—By Charles O. Boutelle, Assistant.
1886	9	263–266	Report of changes in the shore line and beaches of Martha's Vineyard, as derived from comparisons of recent with former surveys.—By Henry L. Whiting, Assistant. Changes discussed; map showing changes in Cotamy Beach, from surveys made in 1846, 1856, 1871, and 1886.—[Illustration 21.]
1886	10	267–279	A report on the Delta of the Delaware.—By Henry Mitchell, Assistant. Joe Flogger Shoal; method of comparing old and new surveys; diagram showing cross section of Joe Flogger Shoal; results of comparisons; table giving comparative dimensions of Joe Flogger Shoal, also a table for lower channel (Blake's) near Joe Flogger Shoal, and a table for upper or main channel, near Joe Flogger Shoal.—[Illustration 22.]
1886	11	281–290	A report of Gulf Stream explorations.—Observations of currents, 1886.—By J. E. Pillsbury, Lieut. U. S. N., Assistant. (*See* Gulf Stream explorations.)

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PHYSICAL HYDROGRAPHY—Continued.

TIDES, CURRENTS, WINDS, AND SHORE-LINE CHANGES DUE TO THE ACTION OF THE SEA—Continued.

Year.	Appendix.	Pages.	Subject and author.
1886	13	409-433	On the circulation of the sea through New York Harbor.—By Henry Mitchell, Assistant. Diagram A, types of the tidal profiles; field work of 1886; recapitulation; current observations, taken by the Naval parties October 1886; East River tides and tidal currents; diagram B, East River tides; table giving lunar intervals of upper and lower restorations of level between Governor's Island and Willet's Point, with synchronous heights at other stations, from eight tides, October 4 to 6, 1886; diagram C, maximum and minimum slopes; table giving a comparison of restorations of level; maximum slope (by reaches) of the East River, October 4 to 6, 1886; comparison of slopes, Governor's Island to Willet's Point; intervals and heights of restoration of level between New York Harbor (Governor's Island) and Long Island Sound (Willet's Point), from observations made in October, 1886; diagram D, of currents; tables of variations of slope and velocity; diagram E shows variations of slope and velocity in East River; miscellaneous; table showing the decomposition of tides; diagram F, decomposition of tides graphically represented; comparison of mean levels, Governor's Island and Willet's Point; concluding remarks.—[Illustrations 34-39.]
1887	6	159-163	On the movements of the sands at the eastern entrance at Vineyard Sound.—By Henry Mitchell, Assistant. A continuation of the discussion of the changes among the Monomoy Shoals; table of tides and currents at the entrance of Vineyard Sound; diagram I, entrance to Vineyard Sound; composition of tidal forces; diagram II, tides at entrance of Vineyard Sound graphically represented; concluding remarks.—[Illustrations 31, 32.]
1887	7	165-172	Fluctuations in the level of Lake Champlain and average height of its surface above the sea.—By Charles A. Schott, Assistant. Introductory remarks; fluctuations of the level of Lake Champlain, as shown by monthly means from daily observations made by the United States Engineers at Fort Montgomery, N. Y., between the years 1871 and 1882; fluctuations in the level of Lake Ontario, shown by monthly means from observations at Charlotte Harbor as a representative station, between the years 1859 and 1881; comparison of the state of Lake Champlain with the amount of rain (and melted snow) during the years 1871-1882; table showing effect of wind; secular variation in the level of Lake Champlain; diagram showing annual variation in the level of Lake Champlain and Lake Ontario, with annual variation in rain fall; diagram showing secular variation in the levels of the two lakes; absolute height of Lake Champlain above the ocean; probable uncertainty of this result.—[Illustration 33.]
1887	8	173-184	Gulf Stream explorations; observations of currents, 1887.—By J. E. Pillsbury, Lieut. U. S. N., Assistant. (*See* Gulf Stream explorations.)
1887	13	269-273	Addendum to Appendix No. 8, report of 1883, on the estuary of the Delaware; table giving physical elements of the estuary of the Delaware, with introductory letter.—By Henry Mitchell, Assistant.
1887	15	301-311	Report on the results of the physical surveys of New York Harbor.—By Henry Mitchell, Assistant. Introductory letter: Part 1—The underrun of the Hudson River; its relation to New York bar; diagram A; underrun in the Hudson in the dry season; tables giving densities at different depths, from observations taken in the summer of 1885; diagram giving currents at different depths in various localities; table giving currents at different depths, from observations for 1885; table giving currents on the outer slope of New York Harbor, 1885; table giving depth of neutral plane below surface; limit of the tide, as affecting the scour of the channels in New York Harbor; recapitulation. Part 2—Courses of the Hudson tides through New York Harbor; table of slopes of the Hudson and East rivers; this subject discussed; diagrams of tides (synchronous) in the tract of the Hudson.—[Illustrations 44-49.]
1888	....	7-12	Bulletin No. 3. Abstract of following paper, bearing same title and with 2 illustrations. (Superseded by second edition, published in 1889.)
1888	9	405-408	Tidal levels and flow of currents in New York Bay and Harbor.—By H. L. Marindin, Assistant.—(12 illustrations.)
1889	....	41-43	Bulletin No. 8. Currents in New York Bay and Harbor. (Second edition.)

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PHYSICAL HYDROGRAPHY—Continued.

TIDES, CURRENTS, WINDS, AND SHORE-LINE CHANGES DUE TO THE ACTION OF THE SEA—Continued.

Year.	Appendix.	Pages.	Subject and author.
1889	....	143-146	Bulletin No. 12. A siphon tide gauge for the open seacoast.—By H. L. Marindin, Assistant.
1889	12	403-407	Encroachment of the sea upon the coast of Cape Cod, Mass., as shown by comparative surveys.—By H. L. Marindin, Assistant.—[1 illustration.]
1889	14	459-460	Recent changes in the south inlet into Edgartown Harbor, Martha's Vineyard.—By H. L. Whiting, Assistant.—[1 illustration.]
1889	16	467-477	Gulf Stream explorations: observations of currents, 1888-'89.—By J. E. Pillsbury, Lieutenant U. S. N., Assistant.—(*See* the sub-heading Gulf Stream explorations.)
1890	10	461-620	The Gulf Stream; a description of the methods employed in the investigation and the results of the research.—By Lieut. J. E. Pillsbury, U. S. N., Assistant.—[25 illustrations and 12 figures.]—(*See* abstract under Gulf Stream explorations.)
1890	11	621-623	Report in relation to a portion of boundary line in dispute between the States of Maryland and Virginia.—By Henry L. Whiting, Assistant.
			NOTE.—The portion of boundary line to be examined and located was near Hog Island, in the Lower Potomac, and its course depended upon the method adopted of measuring the low-water line of the river.
1890	14	691-703	On the use of observations of currents for prediction purposes.—Report by John F. Hayford, Tidal Division.
1890	15	705-714	Comparison of the predicted with the observed times and heights of high and low water at Sandy Hook, N. J., during the year 1889.—[2 illustrations.]—A report by A. S. Christie, Chief of the Tidal Division.
1890	....	175-177	Bulletin No. 18. Table for the reduction of hydrometer observations of salt water densities.—By O. H. Tittmann, Assistant.
			NOTE.—A second edition of this paper is to be prepared by Mr. Tittmann as an Appendix to the Report for 1891.

GULF STREAM EXPLORATIONS.

Year.	Appendix.	Pages.	Subject and author.
1846	4	46-53	Letters on the exploration of the Gulf Stream.—Lieutenant-Commanding George M. Bache.
1847	11	75	Table showing temperatures at depths below 700 fathoms, taken by Lieutenants Commanding C. H. Davis in 1845, George M. Bache in 1846, and S. P. Lee in 1847.—(*See* Sketch.)
1853	....	46-51	Gulf Stream explorations.—(Report.)—[Sketches 15 and 16.]
1853	30	82-83	Examination of specimens of bottom obtained in Gulf Stream.—L. F. Pourtales.
1854	47	156-161	Gulf Stream temperatures.—A. D. Bache. On the distribution of temperatures on and near the Gulf Stream: (1) At different depths; (2) at the same depths on sections across the axis of the Gulf Stream, Table I, probable uncertainty in determination of the maximum and minimum points; (3) connection of the figure of the sea bottom with the distribution of temperature: (4, the "cold wall;" (5) reference to shifting; (6) chart of Gulf Stream.—[Sketches 24 and 25.]—[Errata, pp. 158, 159, 160: 1855, xix.]
1855	....	53-55	Gulf Stream exploration.—(Report.) Programme, Craven's Cape Florida section; soundings by Sands along the Gulf Stream axis; depths; bottom configuration, temperatures and bottoms.
1855	....	84	Gulf Stream deep sea soundings.—(Report.)—[Sketch 38 (H, No. 3).]
1855	54	359	Bottle paper. Current bottle card thrown over near Sandy Hook and picked up at the bar at Santa Cruz, one of the Western Islands.

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PHYSICAL HYDROGRAPHY—Continued.

GULF STREAM EXPLORATIONS—Continued.

Year.	Appendix.	Pages.	Subject and author.
1855	55	360	Gulf Stream bottoms.—J. W. Bailey. On the characteristics of some bottoms from the Cape Florida Gulf Stream section.
1858	32	217–222	Florida Gulf Stream.—E. B. Hunt. Notices of certain anomalies; changes of current depending upon the winds and seasons.
1858	39	248–250	Analysis, microscopical, of specimens of bottom taken in sounding.—L. F. Pourtales. Green and ochraceous incrustation of *Foraminifera*, and jet tint of specimens.
1859	25	306–310	Gulf Stream: distribution of temperature in the water of the Florida channel and straits.—A. D. Bache. Form of bottom; change of temperature with depth; temperature in a direction across the stream; bands of warm and cold water; the "cold wall;" longitudinal section; effects of pressure on Saxton's deep-sea thermometer, under pressure and free from pressure; thermometers Nos. 5 and 10.—[Sketch 35.]
1860	17	165–176	Gulf Stream.—A. D. Bache. General account of the methods used in developing its hydrography, and summary of results obtained: (1) instruments for temperatures; for depth; for obtaining specimens of the bottom; (2) plan of the work; (3) method of discussion of results; (4) results; type curves of law of temperature, with depth at the most characteristic positions; type curves of law of distribution of temperature across the stream; curves of temperature at the same depths; curves of depths at the same temperatures.—Table I, distance of the cold wall from the shore, and widths of the several bands of cold and warm water of the Gulf Stream, measured on the lines of the sections; (5) limit of accuracy of the determinations; II, probable uncertainty in the determination of maximum and minimum points by running the same sections over in different years, by different observers: III, value of probable error of determination of the bands for each section and the average of the whole; (6) figure of the bottom of the sea below the Gulf Stream; (7) general features of the Gulf Stream.—[Sketches 19 to 22.]
1867	15	176–179	Soundings in the Gulf Stream between Key West and Havana.—H. Mitchell. Table I, soundings in the Gulf Stream near the coast of Cuba, 1867: II, current observations.—[Sketch 25.]—(Supplement, 1868, pp. 166-167.)
1867	16	180–182	Fauna of the Gulf Stream.—L. F. Pourtales. Dredgings in the Straits of Florida.
1868	11	166–167	Note on Gulf Stream observations.—H. Mitchell. Decrease of bottom temperature in still-water channels.—(Sequel to 1867, p. 179.)
1868	12	168–170	Report upon dredgings near the Florida Reef.—L. F. Pourtales. Organic specimens; corals, echinoderms, brachiopods, etc.
1869	10	208–219	Report upon deep-sea dredgings in the Gulf Stream during the third cruise of the United States Steamer *Bibb*.—L. Agassiz. Fauna of the submarine zones; reef zone: sedimentary zone; coral slope of living cretacean types; floor of foraminiferine mud; geological inferences; inclination of the reefs: pot holes; formation of oölithic, amorphous, and compact limestones; the Jurassic submarine seam; embryology of corals and formation of colonies by disk embranchment; extinct forms representing modern developmental transitions; lines to be dredged.
1869	11	220–225	The Gulf Stream.—Characteristics of the Atlantic sea bottom off the coast of the United States.—L. F. Pourtales. Manner of dredging; silicious formation; green sand formation.
1882	19	459–461	Recent deep-sea soundings off the Atlantic coast of the United States.—[With references to development of bed of the Gulf Stream.]—By J. E. Pillsbury, Lieutenant U. S. N., Assistant. (One illustration.)

A subject-index to the professional papers contained in the annual reports, etc.—Continued.

PHYSICAL HYDROGRAPHY—Continued.

GULF STREAM EXPLORATIONS—Continued.

Year.	Appendix.	Pages.	Subject and author.
1885	14	495–501	Report on deep-sea current work in the Gulf Stream.—By J. E. Pillsbury, Lieutenant, U. S. N., Assistant, Coast and Geodetic Survey. Letters of instruction; report; description of apparatus devised by Lieut. Pillsbury for observations of deep-sea currents, with diagram and detailed account of its use; observations made, and lines run; chart showing locality of cross section A, between Fowey Rocks and Gun Cay; charts showing positions of current stations, cross section A, Gulf Stream; illustrations 39 to 46 giving a graphic picture of the deep-sea current work.
1886	11	281–290	A report of Gulf Stream explorations.—Observations of currents, 1886.—By J. E. Pillsbury, Lieutenant U. S. N., Assistant. Detailed report of season's work, with a treatment of the subject, under the following heads: I. General characteristics of the Gulf Stream as developed by the observations. II. Daily variation of the stream. III. Monthly variation of the stream. IV. Axis of the stream. V. Effect of wind on the velocity of the stream, and the position of its axis. VI. Depth of the stream, and velocity at different depths. VII. General summary for the guidance of navigators. Plates (23 to 28) presenting curves of observations of currents in the Gulf Stream during 1885 and 1886.
1887	8	173–184	Gulf Stream explorations.—Observations of currents, 1887.—A report by Lieut. J. E. Pillsbury, U. S. N., Assistant. Detailed report of season's work; sections occupied, CC, between Rebecca Shoal and Cuba; DD, between Cape San Antonio, Cuba, and Yucatan; and section F, from Cape Hatteras Shoal in a direction nearly southeast; a treatment of the subject in the following order: (1) General characteristics and limit of the stream at each cross section. (2) Daily variation. (3) Axis of the stream. (4) Depth of the stream, and velocity at different depths. (5) Comparison of results obtained at various sections.—[Illustrations 34–42.]
1889	16	467–477	Gulf Stream explorations.—Observations of currents, 1888–1889.—By Lieut. J. E. Pillsbury, U. S. N., Assistant, U. S. Coast and Geodetic Survey.—(20 illustrations.)
1890	10	461–620	The Gulf Stream.—A description of the methods employed in the investigation and the results of the research.—By Lieut. J. E. Pillsbury, U. S. N., Assistant.—(25 illustrations and 12 figures.) Preface; introduction; general historical account of the Gulf Stream and its investigation up to the time of Franklin; Gulf Stream investigations from the time of Franklin to those made by the U. S. Coast Survey: Gulf Stream investigations made by the U. S. Coast Survey until 1884 and those contemporary with them; outfit of the *Blake* for anchoring at sea and observing the currents; characteristics of the Gulf Stream in the straits of Florida and in the Yucatan Passage; the Gulf Stream off Jupiter Inlet and Cape Hatteras; the equatorial current; causes of the Gulf Stream and of Atlantic currents; conclusions; index.

DEEP-SEA SOUNDINGS, TEMPERATURES, AND DENSITIES.

Year.	Appendix.	Pages.	Subject and author.
1854	54	191–192	Craven's specimen box for deep-sea bottoms.—T. A. Craven. [Sketch 56.]
1857	46	398	Deep-sea sounding apparatus.—Description of a form proposed and used by B. F. Sands. [Sketch 70.]
1857	....	....	Berryman-Brooke's deep-sea sounding apparatus. [Sketch 71.]
1858	37	228–246	Deep-sea soundings.—W. P. Trowbridge. Investigation of the laws of motion governing the descent of the weight and line; formulæ of velocity of descent.—Table I, rates of descent and resistance, in pounds, upon the sinker and line, with one and with two 32-pound shot, attached to a line 0.07 of an inch in diameter; II, same, with 96 and 126 pound weights, deep-sea line; III, influence of different lengths of line moving with the same velocity; ratios of lengths to ratio of resistances; VII, comparison of resistances upon the same lengths of lines of different diameters, moving at the same velocity; VI, influence of lengths at different depths; VIII, same, continued; IX, rates of descent, velocity, resistance to sinker and line, and weight of line in water, from observations made by Joseph Dayman; diameter of line, 2 inches; weight, 96 pounds; specific gravity, 1.3.—[Sketch 38.]—[Errata, p. 235; 1858, p. xxi.]

A subject-index to the professional papers contained in the annual reports, etc.—Continued.

PHYSICAL HYDROGRAPHY—Continued.

DEEP-SEA SOUNDINGS, TEMPERATURES, AND DENSITIES—Continued.

Year.	Appendix.	Pages.	Subject and author.
1858	39	248–250	Analysis, microscopical, of specimens of bottom taken in sounding.—L. F. Pourtales. Green and ochraceous incrustation of *Foraminifera*, and jet tint of specimens.
1859	34	359–364	Deep-sea sounding apparatus.—Description of a form devised by W. P. Trowbridge, and explanation of its method and use. [Sketch 39.]—[Errata, 359, 1860, p. xx.]
1861	11	135–139	Sounding apparatus and log.—W. P. Trowbridge. Results obtained with an instrument devised by him.
1866	5	35–44	Florida Straits.—H. Mitchell. Report on soundings; northern approach; southern approach; difficulties in the way of laying a telegraph cable; remarks upon lines and leads; table of soundings across the Straits of Florida from Sand Key to El Moro, 1866.—[Sketch 17.]
1866	5	139	Berryman apparatus; rates of outrun of line.—(*See* 1857, specimen sounding, Sketch 71.)
1868	12	168–170	Report upon dredgings near the Florida Reef.—L. F. Pourtales. Organic specimens; corals, echinoderms, brachiopods, etc.
1874	14	152	Device for detaching from a line the heavy weight requisite in deep-sea soundings.—[Sketch No. 23.]—Lieut. Com. C. D. Sigsbee.
1874	16	154	Ocean salinometer.—J. E. Hilgard, Assistant.
1876	23	407–409	List of publications relating to the deep-sea investigations carried on in the vicinity of the coasts of the United States under the auspices of the Coast Survey.
1877	10	108–113	Optical densimeter, for ocean water.—J. E. Hilgard, Assistant.
1879	6	95–102	Dredging operations in the Caribbean Sea.—[With two maps.]—Alexander Agassiz.
1880	16	297–340	Bering Sea.—W. H. Dall. Report on the currents and temperatures, and also those of the adjacent waters; sources of information; surface temperature; tables of temperatures; pack ice; summer temperatures; the Kuro Siwo and its extensions; table of North Pacific Sea temperatures; comparison of sea temperatures from observations by the *Challenger*, 1873 and 1875; currents of Bering Sea; observations of the *Tuscarora* and *Venus*; those of Krusenstern, 1804-1806; notes by whalers and others; table of temperatures; of currents; observations off the coast of Asia; in the Arctic in general; in the vicinity of Point Barrow. Supplementary note.—Additional observations in the Arctic Sea; boundary line between the territory of the United States in Alaska and Russia in Asia; diagrams of surface and vertical isotherms; chart of currents.
1880	....	....	Deep-sea sounding and dredging.—A description and discussion of the methods and appliances used on board the Coast and Geodetic Survey steamer *Blake*.—By Charles D. Sigsbee, Lieutenant-Commander, U. S. N., Assistant in the Coast and Geodetic Survey. 221, quarto. (With 54 illustrations.) Washington: Government Printing Office, 1880.
1882	18	451–457	Report on the Siemens electrical deep-sea thermometer.—By Commander J. R. Bartlett, U. S. N., Assistant. Test of thermometer on the U. S. Coast Survey steamer *Blake*, with tables of results obtained at different depths and under different conditions, and a description of the apparatus.—By Werner Suess. [Sketches 48 and 49 and diagrams with text.]
1882	19	459–461	Recent deep-sea soundings off the Atlantic coast of the United States.—By J. E. Pillsbury, Lieutenant, U. S. N., Assistant. A general summary of the operations of the U. S. Coast Survey steamer *Blake* in the examination of the western Atlantic basin during the years 1880, 1881, 1882, and 1883.—[Illustration 50.]
1884	13	435–438	Geology of the sea bottom in the approaches to New York Bay.—By A. Lindenkohl, U. S. Coast and Geodetic Survey Office. Prefatory remarks; characteristics of sea bottom; (1) a well-defined submarine valley; (2) an area of clay bottom extending about 100 miles seaward; (3) a deep ravine at the edge of the continental slope, the Hudson River fiord; geology of the sea bottom in the approaches to New York Bay illustrated.—[Illustration No. 24.]

A subject-index to the professional papers contained in the annual reports, etc.—Continued.

PHYSICAL HYDROGRAPHY—Continued.

DEEP-SEA SOUNDINGS, TEMPERATURES, AND DENSITIES—Continued.

Year.	Appendix.	Pages.	Subject and author.
1884	17	619-621	Description of a model of the depths of the sea in the Bay of North America and Gulf of Mexico.—By J. E. Hilgard, Superintendent. A detailed description of the model; oceanic depressions and terrestrial elevations contrasted; addendum giving effect of an assumed reduction in the depth of the sea of 100 fathoms.—[Illustration No. 25.]
1890	....	175-177	Bulletin No. 18.—Table for the reduction of hydrometer observations of salt-water densities.—Prepared for publication by O. H. Tittmann, Assistant.

SURVEYS AND EXPLORATIONS OF OYSTER BEDS.

1881	11	269-353	Report on the oyster beds of the James River, Virginia, and of Tangier and Pocomoke sounds, Maryland and Virginia.—By Francis Winslow, Master, U. S. N., Assistant, Coast and Geodetic Survey. Preface; instructions; methods of conducting the investigation; (1) delineation of the beds; specimen of record; tides; specimens; bottom and water specimens; substratum of bottom; currents; number of oysters to the square yard; temperature of the water; names and areas; report of the investigation conducted during the summer of 1878; oyster beds of the James River, Virginia; currents; section across James River; Mulberry Point beds; Point of Shoals and Jail Island beds; Blunt Point bed; Thomas Point, Kettle Hole, and White Shoal beds; Brown's Shoal bed; Cruisers Rock and Nansemond Ridge; the fishery and its effects; Tangier and Pocomoke sounds; Fishing Bay beds; Were Point beds; Sharks Fin bed; diagram 1, profiles 1-4; Nanticoke Middle Ground bed; Clump Point Rocks; Horseys Bar and Tylers Rock; Drumming Shoal bed; Cedar Rock; the Cow and Calf beds; diagram 2, profiles 5-8; Turtle-Egg Island bed; Mud Rock; the Muscle Hole bed; diagram 3, profiles 9-12; Piney Island Bar; beds of the Manokin River; beds of the Big Annemessex River; diagram 4, profiles 13-15; Terrapin Sand beds; Pauls bed; bed of Janes Island light-house; the Great Rock; diagram 5, profiles 16-20; the Womans Marsh bed; Thoroughfare beds; California beds; diagram 6, profiles 21-24; Johnsons bed; Oak Hammock Rocks; densities; comparison of densities—Tangier; currents; deposit; effect of gales and ice; Pocomoke Sound; scattered oysters in Pocomoke Sound; diagram 7, profiles 25-31; Buoy Spit bed; Muddy Marsh bed; The Bird bed; Hern Island bed; beds of Guilford Channel; Beach Island bed; Parkers bed; The Brig bed; densities; comparison of densities—Pocomoke; currents; deposits; effect of ice and gales; general information given by oystermen; conclusions; Table I, giving number of oyster dredgers seen in Crisfield Harbor in one day, and number of bushels of oysters taken; Table II, number of young oysters taken; number of oysters taken in one day in the Upper Tangier, Middle Tangier, Lower Tangier, and in the Pocomoke; destruction of oyster beds; their preservation; investigation conducted during the summer and autumn of 1879; instructions; plan of work; illustration 39, cluster of oysters and sponge taken from unworked beds of the Chesapeake; delineation of the beds; beds in the Nanticoke River; beds in the Little Annemessex; beds in Hedges Strait; investigation of the Chesapeake Bay west of Tangier and Smiths Island; illustration 40, cluster of oysters and sponge from unworked beds of the Chesapeake; table showing number of oysters to the square yard; Table I, dredging results—Chesapeake Bay; illustration 41, adult oyster, natural size; Table II, dredging results—Chesapeake Bay; fecundity of the beds in the Sounds; Table I, dredging results—Tangier Sound; table showing the success of spatting at different seasons—Tangier Sound; Table showing the success of spatting in different seasons—Pocomoke Sound; Table II, dredging results—Tangier and Pocomoke sounds; illustration 42, specimen tile No. 7; table showing number of oysters to the square yard in Tangier Sound and in Pocomoke Sound; information obtained from spat-collectors; illustration 43, specimen tile No. 2; investigation of temperatures; investigation of the changes in density of the water; illustration 44, specimen tile No. 6; incidental information; information obtained from "record of statistics;" table showing estimated number of oysters removed in 1879—Upper Tangier, Middle Tangier, Lower Tangier, and Pocomoke Sound; table showing number of oysters removed; conclusions; table showing number of oysters removed from Great Rock and Woman's Marsh; Appendix A, area of oyster beds—Tangier and Pocomoke sounds; illustration 63, Astyris: variety winslovii; Appendix B, description by Assistant Dall of "drill"

A subject-index to the professional papers contained in the annual reports, etc.—Continued.

PHYSICAL HYDROGRAPHY—Continued.

SURVEYS AND EXPLORATIONS OF OYSTER BEDS—Continued.

Year.	Appendix.	Pages.	Subject and author.
			or *astyris* referred to in the report of the operations during the season of 1878; Appendix C, table showing number and class of dredging vessels seen from the *Palinurus* during the season of 1878; Appendix D, form of questions used in collecting information from oystermen; Appendix E, table giving analysis of water from Tangier and Pocomoke sounds and Chesapeake Bay, by Prof. Moore, U. S. Naval Academy; diagrams 9-15, curves showing difference of density of water at bottom; chart of James River, showing approximate limits of oyster beds; upper part of Tangier Sound, chart showing approximate position of oyster beds; lower part of Tangier Sound, chart showing approximate position of oyster beds.—[Illustrations, 39-63.]
1889	....	51-136	Bulletin No. 10.—Report on the Sounds and Estuaries of North Carolina with reference to Oyster Culture.—By Francis Winslow, Lieutenant U. S. Navy, Assistant, U. S. Coast and Geodetic Survey, commanding schooner *Scoresby*.—[2 illustrations.] Table of contents: Introduction; preface; information desired; methods used in the survey; area examined; general description; descriptions of sections, with results of the work in detail; limits of projections, with areas of public and private oyster grounds; specific gravities; general summary of results; general condition of the oyster industry prior to 1887; recommendations for new legislation; history of the Shell-Fish Commission; operation of the new law; method of locating lots; conclusion; appendix; an act to promote the cultivation of shellfish in the State, and form of application for private oyster grounds.
1890	....	179-209	Bulletin No. 19.—On the Sounds and Estuaries of Georgia with reference to Oyster Culture.—A report by J. C. Drake, Ensign U. S. Navy, Assistant, U. S. Coast and Geodetic Survey, commanding schooner *Ready*, 1889-'90.—[7 illustrations.] Preface; methods; limits of the area examined; description of the areas examined; general conclusions; densities; table of areas examined with reference to oyster culture; resolution authorizing the appointment of an oyster commission; State of Georgia; an act for the regulation and protection of oyster culture; form of application for oyster grounds; charts to accompany report on oyster survey of the following sounds, harbors, or rivers of Georgia: Tybee Roads and Wassaw Sound, Ossabaw Sound, Vernon and Ogeechee rivers, St. Catherines Sound, Sapelo Sound, Doboy and Altamaha sounds, St. Simon Sound, Brunswick Harbor and Turtle River, and St. Andrews Sound.

TERRESTRIAL MAGNETISM.

Year.	Appendix.	Pages.	Subject and author.
1845	3	41-43	Extract from a letter addressed by Ferd. H. Gerdes, Assistant, U. S. Coast Survey, to Prof. A. D. Bache, Superintendent, containing remarks upon the change in the magnetic variation within short distances in the Gulf of Mexico.
1854	30	37-40	(Report for 1854.)—Page 39, App. No. 30.—Reference to magnetic observations made at stations in California.—W. P. Trowbridge.
1854	43	142-145	(1844-'45.)—Table of magnetic declination. Results of Coast Survey magnetic observations at 136 stations along the coast of the United States.—[Errata, 144, 145: 1855, p. xix.]
1854	44	146	Meridian lines.—Report of Assistant G. W. Dean on the establishment of meridian lines at Petersburg, Va., and Raleigh and Wilmington, N. C.
1855	47	295-306	(1844-'55.)—Table of magnetic declinations in geographical order, from Coast Survey observations; with notes by A. D. Bache and J. E. Hilgard. Discussion of magnetic declination: (1) Northern part of the Gulf of Mexico; (2) Atlantic coast; (3) Pacific coast.—[Sketch 56.]
1855	48	306-337	(1717-1855.)—Secular variation in the magnetic declination.—C. A. Schott. Discussion of the secular change in the magnetic declination on the Atlantic and part of the Gulf coasts of the United States; Providence, R. I.; Hatboro, Pa.; Philadelphia, Pa.; Boston, Mass.; Cambridge, Mass.; New Haven, Conn.; New York, N. Y.; Charleston, S. C.; Mobile, Ala.; Havana, Cuba; Burlington, Vt.; Chesterfield, N. H.; Salem, Mass.; Nantucket, Mass.; Albany, N. Y.; Washington, D. C.; Pensacola, Fla.—[Sketch 51.]—[Errata, pp. 314, 335; 1855, p. xviii.]

A subject-index to the professional papers contained in the annual reports, etc.—Continued.

TERRESTRIAL MAGNETISM—Continued.

Year.	Appendix.	Pages.	Subject and author.
1855	49	337	(1855.)—Magnetic observations.—C. A. Schott. Results for declination, dip, and horizontal intensity, at sixteen eastern stations, July to September, 1855.
1856	28	209–225	(1839–1855.)—Terrestrial magnetism.—Discussion relative to its distribution in the United States.—A. D. Bache and J. E. Hilgard. Methods and sources used; corrections for secular variations; construction of maps (Sketches 61 and 62); comparison of maps for declination, dip, and intensity; supplementary note (Mexican observations); Table I, Atlantic, Gulf, and Pacific sections; II, near parallel 35°, by J. C. Ives, Whipple's expedition; III, from various new sources—lakes, territories, Panama; IV, residual difference between the Coast Survey observations, reduced to 1850, and the values obtained from the accompanying map—[Sketches 61 and 62.]
1856	29	226	Magnetic observations.—C. A. Schott. Methods used in observations of the present year; magnet H.
1856	30	227	(1856.)—Magnetic elements.—C. A. Schott. Results of observations for declination, dip, and intensity at stations in Delaware, Maryland, and Virginia.
1856	31	228–235	(1792–1855.)—Secular change of declination; Western coast.—C. A. Schott. List of magnetic declinations observed on the western coast from the earliest to the present ones, arranged in order of geographical latitudes.—Annual change; (1) San Diego; (2) Monterey; (3) San Francisco; (4) Cape Mendocino: (5) Cape Disappointment.—Recapitulation of results for secular change.
1856	32	235–245	(1780–1855.)—Secular change of inclination; Atlantic coast.—C. A. Schott. Toronto, Canada; Albany and Greenbush, N. Y.; Cambridge, Mass.; Providence, R. I.; West Point and Cold Spring, N. Y.; New Haven, Conn.; New York, N. Y.; Philadelphia, Pa.; Washington, D. C.; Baltimore, Md.; recapitulation of results.—Table I, geographical positions and number of dip observations; II, formula for each station; III, probable error, epoch of minimum dip and annual variation in current year.—[Sketch 63.)
1856	33	246–249.	(1790–1855.)—Secular change of inclination; western coast.—Approximate determination of the secular change of inclination.—C. A. Schott. Table of observation made up to the present time; deductions therefrom—(1) San Diego; (2) San Pedro; (5) Monterey; (6) San Francisco; (8) Fort Vancouver; (10) Cape Disappointment.
1857	32	334–342	Magnetism.—Report upon the gradual loss of magnetism of the several magnets in use in the Survey of the Coast.—C. A. Schott. Account of magnets: S 8, C 32, C 9, D, C 6, H, and Smithsonian magnet used in 1855.—Table: Recapitulation of values for magnets severally, and discussion.—[Sketch 68.]
1858	24	191, 192	(1856–1858.)—Magnetic elements.—Continuation.
1858	25	192–195	(1680–1850.)—Secular variation of magnetic declination at Hatboro, Pa.—C. A. Schott. Discussion and development of an intermediate period.—Table of declinations from 1680 to 1850.—Diagram.—[Errata, p. 193; 1858, p. xxi.]
1858	26	195–197	(1809–1857.)—Secular variation at Washington, D. C.—C. A. Schott. Declination from 1809 to 1857.—Dip from 1839 to 1858.
1859	16	172–175	(1858.)—Variation of the compass.—General table for the use of navigators.—[Sketch 38.]
1859	22	278–295	Discussion of the magnetic and meteorological observations made at the Girard College Observatory, Philadelphia, in 1841, 1842, 1843, 1844, and 1845.—A. D. Bache.—[Sketch 37.]—[Errata, pp. 279, 280, 293: 1860, p. xx.] Part I. Investigation of the eleven-year period in the amplitude of the solar-diurnal variation and of the disturbances of the magnetic declination.
		278	Introduction.
		279	Separation of disturbances and establishment of normal readings of the declinometer.
		285	Analytical expressions of the regular solar-diurnal variation of the declination.
		286	Inequality of the amplitude due to the eleven (or ten) year period.
		287	Discussion of the number of disturbances of the declination; their annual inequality.
		290	Diurnal inequality of the number of disturbances of the declination.

A subject-index to the professional papers contained in the annual reports, etc.—Continued.

TERRESTRIAL MAGNETISM—Continued.

Year.	Appendix.	Pages.	Subject and author.
		290	Deflections by disturbances; their mean annual amount; effect of the eleven (or ten) year period.
		292	Deflections by disturbances; their mean diurnal amount.
		295	Connection of the frequency of the solar spots with the changes in the amplitude of the diurnal variation of the declination.
1859	23	296	(1859.)—Declination, dip, and intensity.—C. A. Schott. Results of observations made by him in Canada, Maine, New Hampshire, Vermont, Massachusetts, and Connecticut.—Footnote on disturbances.
1859	24	296-305	(1680-1860.)—Secular change in declination.—C. A. Schott. Variation of the needle on the coasts of the United States for every tenth year since 1680; formulas expressing secular change, used for calculating the tabular values for Group I, stations between Portland, Me., and Williamsburg, Va., with table of observations made between 1680 and 1860; for Group II, southern stations and western coast.—Record of all observed declinations made use of in the above paper not heretofore published in the Coast Survey Reports.
1860	21	268-271	(1860.)—Eclipse expedition to Aulezavik Island, Labrador. Report on the determination of the magnetic elements by Edward Goodfellow, Assistant, with notes by C. A. Schott, Assistant.
1860	23	293-312	Discussion of the magnetic and meteorological observations made at the Girard College Observatory, Philadelphia, in 1841, 1842, 1843, 1844, and 1845.—A. D. Bache.
			Part II. Investigation of the solar-diurnal variation in the magnetic variation, and its annual inequality.
		293	Investigation of the solar-diurnal variation of the declination.
		302	Its semiannual inequality.
		303	Analytical and graphical exhibition of the solar-diurnal variation for each month, summer, winter, and year.
		307	Maxima and minima, and times of average value of the declination; diurnal range.
		309	Annual variation of the declination.
1860	24	312-324	Discussion of the magnetic and meteorological observations made at the Girard College Observatory, Philadelphia, in 1840, 1841, 1842, 1843, 1844, and 1845.—A. D. Bache.
			Part III. Investigation of the influence of the moon on the magnetic declination.
		312	Lunar influence on the magnetic declination; tabulation of results according to the moon's hour angle.
		318	Comparison of lunar-diurnal variation for three epochs.
		319	Resulting lunar-diurnal variation.
		321	Inequality in the lunar-diurnal variation.
		324	Investigation of deflections depending upon lunar phases; variation in declination and in parallax.
1860	25	324-326	Solar spots.—Report of Assistant C. A. Schott on the results of observations made during the first seven months of the year 1860.
1860	26	326-349	Key West magnetic station.—Description of instruments and plan of magnetic observatory; with results.—W. P. Trowbridge. Declinometer, recording cylinder, and clock; vertical-force magnetometer; adjustments; mean daily range of temperature for each month, 1851, 1852, and monthly range for four years; mean monthly temperature for fourteen years; lamps; scale measurements; temperature coefficients of the horizontal and vertical forces of magnets; photographic arrangements; magnet H—axis and intensity; dip; scale values for intensity magnets—tables and computation; experiments for temperature coefficients of horizontal-force magnet, with hot water and ice.—[Sketches 23 and 24.]
1860	27	350, 351	Eastport station, Maine.—General description of magnetic station.—L. F. Pourtales.
1860	28	351, 352	Declination, dip, and intensity at various stations (supplementary to 1856, p. 227, and 1858, p. 191).
1860	29	352	Declination, dip, and intensity, determined in 1860 on the coasts of Massachusetts, Long Island, and New Jersey.—C. A. Schott.
1861	22	242-251	Secular change of intensity.—C. A. Schott. Discussion of observations made on the Atlantic, Gulf, and Pacific coasts of the United States; intensity statistics; notes; table of annual change for Atlantic and Pacific groups.

A subject-index to the professional papers contained in the annual reports, etc.—Continued.

TERRESTRIAL MAGNETISM—Continued.

Year.	Appendix.	Pages.	Subject and author.
1861	23	251–256	New discussion of the distribution of the magnetic declination on the coast of the Gulf of Mexico, with a chart of the isogonic curves for 1860.—C. A. Schott.
1861	24	256–259	New discussion of the distribution of the magnetic declination on the coasts of Virginia, South Carolina, and Georgia, with a chart of the isogonic curves for 1860.—C. A. Schott.
1861	25	259–261	Solar spots.—Abstract of observations made at the Coast Survey Office.—C. A. Schott.
1862	15	161–185	Discussion of the magnetic and meteorological observations made at the Girard College Observatory, Philadelphia, in 1840, 1841, 1842, 1843, 1844, and 1845.—A. D. Bache.—[Sketch 48.]—[Errata, pp. 178, 182: 1862, p. IV.]
			Part IV. Investigation of the eleven (or ten) year period and of the disturbances of the horizontal component of the magnetic force.
		161	Instrumental notice.
		162	Correction of readings for changes of temperature; scale values.
		169	Correction for progressive instrumental change; hourly normals for each month.
		173	Horizontal intensity; absolute value; effect of the loss of magnetism of the bar; secular change.
		174	Separation of the larger disturbances.
		175	Corrected normals.
		178	Investigation of the eleven (or ten) year period, from changes in the amplitude of the solar-diurnal variation.
		180	Eleven (or ten) year inequality, as indicated by the disturbances.
		182	Analysis of the disturbances; annual and diurnal variation.
		185	Classification of disturbances according to their magnitude.
1862	16	186–200	Discussion of the magnetic and meteorological observations made at the Girard College Observatory, Philadelphia, in 1840, 1841, 1842, 1843, 1844, and 1845.—A. D. Bache.—[Sketch 48.]
			Part V. Investigation of the solar-diurnal variation and of the annual inequality of the horizontal component of the magnetic force.
		186	Preparation of hourly normals for each month.
		193	Regular solar-diurnal variation.
		194	Semiannual inequality in the diurnal variation.
		195	Analysis of the solar-diurnal variation.
		198	Epochs of maxima and minima; amplitude; epochs of average value.
		200	Annual variation of the force.
1862	17	202–212	Discussion of the magnetic and meteorological observations made at the Girard College Observatory, Philadelphia, in 1840, 1841, 1842, 1843, 1844, and 1845.—A. D. Bache.
			Part VI. Investigation of the influence of the moon on the magnetic horizontal force.
		202	Number of observations for lunar discussion and their distribution according to western and eastern hour angles of the moon; differences from monthly normals, arranged for moon's hour angles.
		206	Lunar-diurnal variation for two periods.
		207	Lunar-diurnal variation in summer and winter.
		209	Analysis of the lunar-diurnal variation.
		210	Investigation of the horizontal force in reference to lunar phases.
		211	Influence of the moon's changes of declination.
		212	Influence of the moon's changes of distance.
1862	18	212	Results for declination, dip, and horizontal intensity in Pennsylvania, in the District of Columbia, and in New York.—C. A. Schott.
1862	19	212–229	Abstract of results of a magnetic survey of Pennsylvania and parts of adjacent States in 1840 and 1841, with some additional results of 1843 and 1862.—A. D. Bache.
			Declinations observed by him in 1840 and 1841; tabular comparison of secular changes in 1840, 1841, and 1862; chronometric results for longitude; geographical positions; distribution of declination for 1842.0; general table of results referred to common epoch, 1842.0; comparison of observed and computed values; dip, distribution of, and isoclinal lines for 1842, Groups 1 to 4; correction to epoch; comparison of observed and computed dip; horizontal intensity and isodynamic lines for 1842; tabular formation of groups for the analytical expression of the distribution of horizontal force referred to 1842.0; comparison of observed and hypothetical computed values; representation of the total force.—[Sketch 47.]
1862	20	230, 231	Declination, dip, and intensity at various stations (supplementary to lists given in Annual Reports of 1856, 1858, and 1860, pp. 351, 352).

A subject-index to the professional papers contained in the annual reports, etc.—Continued.

TERRESTRIAL MAGNETISM—Continued.

A subject-index to the professional papers contained in the annual reports, etc.—Continued.

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A subject-index to the professional papers contained in the annual reports, etc.—Continued.

TERRESTRIAL MAGNETISM—Continued.

Year.	Appendix.	Pages.	Subject and author.
1874	8	72–108	Secular change of magnetic declination in the United States and other parts of North America; new discussion.—C. A. Schott. Collection of magnetic declinations, Halifax, Nova Scotia; Quebec, Canada; York Factory, Hudson Bay; Portland, Me.; Burlington, Rutland, Vt.; Portsmouth, N. H.; Newburyport, Salem, Boston, Cambridge, Nantucket, Mass.; Providence, R. I.; Hartford, New Haven, Conn.; Albany, Oxford, Buffalo, N. Y.; Erie, Pa.; Cleveland, Ohio; Detroit, Mich.; New York and vicinity, N. Y.; Hatborough, Philadelphia, Pa.; Washington, D. C.; Cape Henry, Va.; Charleston, S. C.; Savannah, Ga.; Key West, Fla.; Havana, Cuba; Kingston, Jamaica; New Orleans, La.; Vera Cruz, City of Mexico, Acapulco, San Blas, Mexico; Panama, New Granada; San Diego, Monterey, Point Pinos, San Francisco, Cal.; Cape Disappointment, W. T.; Sitka, Captains Harbor, Unalashka Island, Alaska; Eastport, Me.; Hanover, Chesterfield, N. H.; Toronto, Canada; Baltimore, Md.; Williamsburg, Va.; New Berne, N. C.; Mobile, Florence, Ala.; St. Louis, Mo.; Cape Mendocino, Cal.; Nootka, Vancouver Island; Petropaulovski, Kamtchatka; table of empirical expressions for magnetic declination; comparison of magnetic declination observed and computed; table, number of observations at each place; table of decennial values of the magnetic declination.
1874	9	109–130	Magnetic observations, Key West, Fla.—C. A. Schott. Monthly results for magnetic declination, 1860-1866; annual effect of the secular change of declination; annual variation of the declination; observed annual variation of the declination at stations near the Atlantic seaboard; monthly values for magnetic dip at Key West; annual effect of the secular change in the dip; monthly values for horizontal intensity at Key West; annular effect of the secular change in the horizontal intensity; annual variation in the horizontal intensity; general table of results from absolute measures of the magnetic declination, dip, and intensity; differential measures of changes in magnetic declination from the Brooke magnetographs at Key West, 1860-1866; monthly means of hourly readings from the photographic traces of the fixed declination at Key West; recapitulation of monthly means of declinometer readings; permanency in the line of detorsion in the suspension skein; discussion of the disturbances of the magnetic declination; monthly normals of hourly readings of the declinometer at Key West; mean monthly normals of hourly readings from observations extending over six years; number of disturbances during six successive years; distribution of disturbances in the yearly period; in the daily period; average magnitude of disturbances during successive years; in the yearly period; in the daily period; solar diurnal variation in the magnetic declination at Key West for the epoch 1863.3; the same between 1860 and 1866; the same at Philadelphia for the epoch 1842.5; diagram; characteristic features of the daily variation; eleven-year inequality in the solar diurnal variation; mean annual normals of hourly readings of the declinometer for six years, 1860-1866, at Key West; mean annual normal deflections at each hour.
1875	16	251–278	Terrestrial magnetism.—C. A. Schott. Instructions for magnetical observations.—(Reprinted from Appendix No. 14, Report of 1872.) (1) Determination of the magnetic declination; sketch; adjustment of the declinometer; example of scale-reading; magnetic declination; ordinary adjustments of the theodolite; diagram; example of record and reduction; solar diurnal variation of declination at Toronto, Canada, Philadelphia, and Key West; (2) determination of the magnetic inclination; reversal of the poles of dipping needles; diagram No. 29, of dip circle; 29 B, dip circle; magnetic dip; specimen of record for finding magnetic meridian; (3) absolute and relative measures of the magnetic force; the magnetometer; observations of deflections; forms 1, 2; observations of oscillations; forms; example to observations of deflections for value of q of magnet H.
1876	21	400	Chart of magnetic declination in the United States, 1875.—J. E. Hilgard.
1877	7	96–97	Magnetic observatory at Madison, Wis.—C. A. Schott.
1879	....	50	Secular change of the magnetic declination in the United States and at some foreign stations.—(Third edition; two illustrations. Separately printed.)
1879	9	124–174	Secular change of magnetic declination in the United States and at some foreign stations.—(Fourth edition, June, 1881.)—C. A. Schott.—(A third edition was published separately June, 1879.) Magnetic declination, definition; solar diurnal variation; annual variation; lunar inequalities; magnetic disturbances; historical note;

A subject-index to the professional papers contained in the annual reports, etc.—Continued.

TERRESTRIAL MAGNETISM—Continued.

Year.	Appendix.	Pages.	Subject and author.
			the needle used among the Chinese and Norwegians; the declination; isogonic charts; secular variation of the declination; analytical expression of the secular change of the declination; collection of magnetic declination for the discussion of the secular change; Paris, France; Halifax, Nova Scotia; Quebec, Montreal, Canada; York Factory, Hudson Bay; Portland, Me.; Burlington, Rutland, Vt.; Portsmouth, N. H.; Newburyport, Salem, Boston, Cambridge, Nantucket, Mass.; Providence, R. I.; Hartford, New Haven, Conn.; Albany, Oxford, Buffalo, N. Y.; Toronto, Canada; Erie, Pa.; Cleveland, Ohio; Detroit, Mich.; St. Louis, Mo.; New York and vicinity, N. Y.; Philadelphia, Harrisburg, Pa.; Baltimore, Md.; Washington, D. C.: Cape Henry, Va.; Savannah, Ga.; Key West, Fla.; Havana, Cuba; Kingston, Jamaica; Panama, New Granada; Rio Janeiro, Brazil; Mobile, Ala.; New Orleans, La.; Vera Cruz, City of Mexico, Acapulco, San Blas, Mexico; Magdalena Bay, Lower California; San Diego, Monterey, Point Pinos, San Francisco, Cal.; Cape Disappointment, W. T.; Kailua, Hilo, and Kealakekua Bays, Owhyhee, Sandwich Islands; Honolulu, Oahu, Sandwich Islands; Sitka, Alaska; Captains Harbor, Unalashka; Petropaulovski, Kamtchatka; St. Johns, Newfoundland; Eastport, Me.; Hanover, Chesterfield, N. H.; Sault Ste. Marie, Grand Haven, Mich.; Williamsburg, Va.; New Berne, N. C.; Florence, Ala.; Bermuda Islands; San Antonio, Tex.; Omaha, Nebr.; Council Bluffs, Iowa; Salt Lake City, Utah; Cape Mendocino, Cal.; Port Townsend, W. T.; Nee-ah Bay, W. T.; Nootka, Vancouver Island.—Table I, formula for magnetic declination at various places; Table II, comparison of observed and computed magnetic declinations; Sketch No. 38; Table III, number of observations; apparent probable error of observation; Sketch No. 37; Sketch No. 39; Table IV, decennial values of the magnetic declination computed from preceding equations.
1880	19	412–417	Variation of the compass off the Bahama Islands at the time of the landfall of Columbus in 1492.—C. A. Schott. Remarks on the early use of the compass; at the time of Columbus; reckoning time; notes on the voyages of Columbus; line of no variation; corrections to the agonic line; track of Columbus across the Atlantic in 1492 in tabular form; conclusions.—[Sketch No. 84.]
1881	8	126–158	Directions for magnetic observations with portable instruments.—(Third and enlarged edition, with 4 plates.)—By Charles A. Schott, Assistant. Introductory remarks; selection of stations; I, determination of the magnetic declination; definition; finding the true meridian: adjustment of the theodolite and alt-azimuth instrument; formulæ for determining azimuth and time; examples of record, and reductions from sun observations and from observations on Polaris; adjustment of the declinometer and magnetometer; observations for magnetic axis and scale values, with examples; table of solar diurnal variation of the declination at Toronto, Canada, at Philadelphia, Pa., and at Key West, Fla.; tables of the times and azimuths of Polaris at elongation, for the use of surveyors in determining the true meridian; observations for magnetic declination; II, determination of the magnetic inclination; description of instrument; adjustment of dip circle; reversal of poles of dipping needles; observations for inclination or dip, with example; observations of dip by means of a loaded needle (the Mayer method), with example of record and reduction; determination of the relative total intensity by means of the dip circle in connection with deflecting weights, as devised by Rev. H. Lloyd, with formulæ and example; determination of relative total intensity by means of the dip circle, combining deflections by gravity and magnetism, by Dr. Lloyd's method, with formulæ and example; III, absolute and relative measures of the magnetic force; units of measure of the magnetic force; description and use of the magnetometer; observations of deflections, with examples of record and reduction; determination of magnetic constants; observations of oscillations, with example of record and reduction; corrections for inequality of temperature; example of observations of deflection for value of q (temperature coefficient); introduction of absolute for relative values of the horizontal force, as determined by oscillations alone; concluding remarks; formula for total force; constants for the conversion of intensity into different units; list of standard works on magnetism; illustrations of the different forms of magnetometers, and of the Kew dip circle.—[Illustrations 34–37.]
1881	9	159–224	Terrestrial magnetism.—Collection of results for declination, dip, and intensity, from observations made by the U. S. Coast and Geodetic Survey between 1833 and 1882, July.—By Charles A. Schott, Assistant. Introductory remarks; explanation of the tables of magnetic results; tables of magnetic results arranged by States and Territories in alphabetical order, with a table headed "Foreign countries," ending with a description of stations arranged in same order.

A subject-index to the professional papers contained in the annual reports, etc.—Continued.

TERRESTRIAL MAGNETISM—Continued.

Year.	Appendix.	Pages.	Subject and author.
1882	12	211–276	On the secular variation of the magnetic declination in the United States and at some foreign stations.—(Fifth edition, November, 1882.)—By Charles A. Schott, Assistant. Introductory remarks; solar-diurnal variation; annual variation; lunar inequalities; secular variation; magnetic disturbances; historical note; the declination; isogonic charts; the secular variation of the declination; analytical expression of the secular variation of the magnetic declination; collection of magnetic declinations, observed at various places in the United States and at some foreign stations, from the earliest to the present time, and found suitable for the investigation of the secular variation; Table I, formulæ expressing the magnetic declination at various places and for any time within the limits of observation, deduced from the preceding collection of results; Table I (*b*), expressions for the magnetic declination at subordinate stations; Table II, comparison of observed and computed magnetic declinations; Table III, annual change of the declination and other data; Sketches 33, 36, graphically representing the secular variation at Baltimore, Md., San Francisco, Cal., and at Paris, France; Sketch 34, showing the position of the agonic line for 1790 and 1885, and annual change of the magnetic declination for the epoch 1885; chart of the secular change in the position of the agonic line of the North Atlantic between 1500 and 1900; Table IV, decennial values of the magnetic declination.—[Illustrations 33–36.]
1882	13	277–328	Distribution of the magnetic declination in the United States at the epoch, January, 1885, with three isogonic charts and one plate.—By Charles A. Schott, Assistant. Prefatory remarks; method of forming tables of observed magnetic declinations and corresponding values referred to epoch, January, 1885; a chart showing disturbed isogonics; table of results for Alaska, formed with a view of expressing the declination to 1885 in a function of the latitude ϕ and the longitude λ; discussion by Lloyd's formula; table of magnetic declinations, for the most part observed in the present century, reduced to the epoch, January 1, 1885, which forms the basis for the construction of three isogonic charts of the United States, Nos. 38, 39, and 40.
1882	14	329–426	Records and results of magnetic observations made at the charge of the "Bache fund" of the National Academy of Sciences, from 1871 to 1876.—Executed under the direction of J. E. Hilgard, M. N. A. S.; data collated and abstracts prepared by H. W. Blair, Assistant. Prefatory remarks; magnetic survey, 1871–'72; descriptions of stations; declinations for 1871–'72; table of declinations, with an explanation of table; horizontal intensity for 1871–'72; method of observing; tables of results for horizontal intensity, arranged by stations; table of general results for 1871–'72; declination, dip, horizontal intensity; descriptions of stations for 1873; table of results for declination for 1873; observations for local time; observations for dip; observations for horizontal intensity; general results for 1873; descriptions of stations for 1874; observations for declination for 1874; observations for local time; observations for dip; observations for intensity; general results for 1874; descriptions of stations for 1875; observations for declination; observations for local time; observations for declination, continued; observations for local time, continued; 1876, observations for declination; observations for dip; observations for horizontal intensity; general results for 1876; summary of results, 1871 to 1876.
1883	13	323–365	Account and results of magnetic observations made under the direction of the U. S. Coast and Geodetic Survey, in co-operation with the U. S. Signal Office, at the U. S. Polar Station, Ooglaamie, Point Barrow, Alaska.—Lieut. P. Henry Ray, A. S. O., commanding post; reduction and discussion by Charles A. Schott, Assistant. Table of contents; Part I, introduction; instructions and notes for the guidance of the observers to be stationed at Point Barrow, Alaska, and at Lady Franklin Bay, north of Smith Sound, Arctic Ocean, with a plan for magnetic house for Point Barrow; memorandum furnished Point Barrow relief party, with plan for new observatory; notes on the mounting; the adjustment and the determination of instrumental constants of the Brooke differential magnetometers; (1) the declination or unifilar magnetometer, (2) the horizontal force or bifilar magnetometer, (3) the vertical force or balance magnetometer; geographical position of Ooglaamie Station, Alaska; sketch of U. S. Polar Station, Ooglaamie, Alaska; Part II, absolute measures; monthly values of the magnetic declination, dip, and intensity at Ooglaamie, December, 1881, to August, 1883; Part III, differential measures; hourly variations of the declination, horizontal, and vertical intensities, with bimonthly term-day readings, at Ooglaamie, December, 1881, to August, 1883; adjustments of the Brooke differential magnetometers;

A subject-index to the professional papers contained in the annual reports, etc.—Continued.

TERRESTRIAL MAGNETISM—Continued.

Year.	Appendix.	Pages.	Subject and author.
			recapitulation of monthly mean values (inclusive of disturbances) of hourly readings of Brooke declinometer at Ooglaamie, Alaska, 1882–'83; solar-diurnal variation of the declination, inclusive of disturbances, with a graphical representation; separation of the larger magnetic variations or so-called disturbances and their discussion; the bifilar magnetometer.—[Illustration 34.]
1885	6	129–274	The geographical distribution and secular variation of the magnetic dip and intensity in the United States.—By Charles A. Schott, Assistant. Prefatory letter; introduction; Part I, explanation of the general table; Table I, observed magnetic dips and horizontal and total magnetic intensities in the United States and adjacent regions, arranged alphabetically; Part II, secular variation of the magnetic dip in the United States; introductory remarks; discussion of dip by least squares; Table II, annual values of observed magnetic dip at prominent stations and comparison of observed and computed dips; two groups of stations exhibiting for every fif h year change in dip, from 1830 to 1885, to be used in connection with secular variations of the horizontal component of the force, and of the total force; type curves of the secular variation of the dip; Part III, secular variation of the horizontal component of the magnetic force and of the total intensity in the United States; Table III, annual values of observed magnetic horizontal force at prominent stations; three type curves showing secular variation of the horizontal intensity—first, for the northeastern part of the United States; second, for the eastern part of the United States; third, for the western coast of the United States; secular variation of the total intensity of the magnetic force; secular variation of the direction of a freely-suspended magnetic needle, with a type curve, for the New England States, from 1820 to 1885; construction of isomagnetic maps of the United States, showing the distribution of the dip, and of the horizontal component and total value of the earth's magnetic intensity, for the epoch, January 1, 1885.—[Illustrations 19–24.]
1885	7	275–284	Collection of some magnetic variations off the coast of California and Mexico, observed by Spanish navigators in the last quarter of the eighteenth century.—Communicated by George Davidson, Assistant. Prefatory letter; table of results obtained during the voyage of the frigate Santiago for discovery of north coast of California; table of results obtained by frigate Santiago and schooner Sonora; table of results obtained by Sr. Virey and Antonio Bucareli, commanding two frigates in expedition of 1779; table of results obtained during the voyage of 1788, in vessels Princessa and San Carlos, northern coast of California; table of results obtained during the voyage of the packet San Carlos from Ounalaska to San Blas (coincidently with frigate Princessa); table of results obtained during the voyage from San Blas to Nutka, 1790; record of the packet Philipino, commanded by Fidalgo in his voyage of discovery, in 1790, from Nutka to Prince William, Cooks River, and return to Monterey; record of the sloop Princess Royal, voyage from Santa Cruz to Straits of Fuca, year 1790, commanded by Don Manuel Quimper.
1886	12	291–407	The secular variation of the magnetic declination in the United States and at some foreign stations (sixth edition, greatly enlarged, April, 1887).—By Charles A. Schott, Assistant. Introduction; the magnetic declination; the solar-diurnal variation; the annual variation; the secular variation: magnetic disturbances or storms; historical note; the declination; isogonic charts; the secular variation of the declination; analytical expression of the secular variation of the magnetic declination; illustration representing graphically the secular variation of the magnetic declination at Paris, France, from 1540 to 1900; collection of observed magnetic declinations suitable for the investigation of the secular variation; Group I, series of magnetic stations, mainly on the Atlantic coast, and in the region east of the Appalachian range, 43 stations; results for Group I, with an analytical expression (in which the magnetic declination is expressed as a function of the time) for each station: Group I, comparison of observed and computed magnetic declinations; results for Group I, completed; Group II, series of magnetic stations, mainly in the central part of the United States, between the Appalachian and Rocky Mountain ranges, 24 stations; results for group, with an analytical expression for each station in which the magnetic declination is expressed as a function of the time; Group II, comparison of observed and computed magnetic declinations; results for Group II completed; Group III, collection of magnetic declinations from the earliest to the present time, observed on or near the Pacific coast of the United States and west of the Rocky Mountains and extending over the region from the Isthmus of Tehuantepec, Mexico, northward to Bering Strait and the Arctic Ocean, coast of Alaska; subdivision

A subject-index to the professional papers contained in the annual reports, etc.—Continued.

TERRESTRIAL MAGNETISM—Continued.

Year.	Appendix.	Pages.	Subject and author.
			into groups from A to G; thirty-nine magnetic stations, mainly on the Pacific coast and in the region west of the Rocky Mountains; results for Group III, with an analytical expression for each station in which the magnetic declination is expressed as a function of time; Group III, comparison of observed and computed magnetic declinations; results for Group III completed; graphical illustration of the secular variation, illustration No. 31; secular change in the position of the agonic line of North Atlantic between 1500-1900, illustration No. 33; progressive change in the secular variation, with a discussion of the subject; the probable errors of some of the early observations.—[Illustrations 29-33.]
1887	10	207-210	The magnetic work of the Greely Arctic Expedition.—Abstract of a report by Charles A. Schott, Assistant. A short historical account of the expeditions sent out in command of Lieut. Greely and Lieut. Ray; astronomical and magnetic work of Sergeant Israel; magnetic observatory at Fort Conger; determination of latitude, longitude, and azimuth; the number of magnetic observations and scheme for observing the declination; solar-diurnal variation; annual variation; hourly observations; term-day and term-hour observations; observations of oscillations; observations for dip; dates of aurora displays; tables of magnetic results derived from the work of other Arctic explorers; annual change in declination in this region; importance of a redetermination of the American pole of dip.
1888	....	25-28	Bulletin No. 5.—The value of the "Arcano del Mare" with reference to our knowledge of the magnetic declination in the earlier part of the seventeenth century.—(Two illustrations.)—By C. A. Schott, Assistant.
1888	....	29-33	Bulletin No. 6.—Secular variation in the position of the agonic line of the North Atlantic and of America between the epochs 1500 and 1900 A. D.—(Three illustrations.)—By Charles A. Schott, Assistant.
1888	....	35-40	Bulletin No. 7.—Historical review of the work of the Coast and Geodetic Survey in connection with terrestrial magnetism.—By Charles A. Schott, Assistant. (Four illustrations.)
1888	6	167-176	(Same title as Bulletin No. 5—1888.) The value of the Arcano del Mare, etc. (Two illustrations.)
1888	7	177-312	The secular variation of the magnetic needle in the United States and at some foreign stations.—By Charles A. Schott, Assistant. (Seventh edition, June, 1889.) Introduction; the magnetic declination; the solar-diurnal variation; the annual variation; the variation depending on the solar rotation; the lunar inequalities; the secular variation; plate showing secular variation of the magnetic declination at Paris, France; magnetic disturbances or storms; historical note; the declination: isogonic charts; the secular variation of the declination; analytical expression of the secular variation of the magnetic declination; collection of observed magnetic declinations suitable for the investigation of the secular variation; Group I.—Series of magnetic stations mainly on the Atlantic coast and in the region east of the Appalachian range, list of stations and explanation of tables; Group I.—Collection of observed magnetic declinations, eastern series; results for Group I; Group I.—Comparison of observed and computed magnetic declinations; results for Group I continued; Group II.—Series of magnetic stations mainly in the central part of the United States between the Appalachian and Rocky Mountain ranges; results for Group II; Group II.—Comparison of observed and computed magnetic declinations; results for Group II continued; Group III.—Collection of magnetic declinations from the earliest to the present time, observed on or near the Pacific coast of the United States and west of the Rocky Mountains, and extending over the region from the Isthmus of Tehuantepec, Mexico, northward to Bering Strait and the Arctic Ocean, coast of Alaska; map showing isogonic lines for the year 1783, constructed from observations made by Spanish navigators between 1774 and 1790, San Blas, Mexico, to Vancouver Island; results for Group III; Group III.—Comparison of observed and computed magnetic declinations; graphical illustration of the secular variation and of the annual change (plate and text); secular variation in the position of the agonic line of the North Atlantic and of America between the epochs 1500 and 1900 A. D. (1 plate); plate showing isogonic curves of 1700 to 1750 A. D.; progressive change in the secular variation; early attempts to locate the North American magnetic pole.

A subject-index to the professional papers contained in the annual reports, etc.—Continued.

TERRESTRIAL MAGNETISM—Continued.

Year.	Appendix.	Pages.	Subject and author.
1889	11	233–402	The distribution of the magnetic declination in the United States for the epoch of 1890. Table of contents; list of illustrations; introduction; retrospective view of work done by the Coast and Geodetic Survey relating to magnetic declinations; theory and effect of local disturbances in the distribution of the declination, dip, and intensity; collection and tabular arrangement of magnetic declinations; general distribution of data in the States, Territories, and other geographical divisions; table of observed declinations and values reduced to the year 1890; construction of the isogonic curves for the United States (exclusive of Alaska); distribution of the declination in Alaska and adjacent regions; establishment of an analytical expression for the distribution in Alaska; construction of the isogonic curves for Alaska; definition of magnetic meridians and parallels, construction of magnetic meridians for the United States (exclusive of Alaska). Illustrations: Plate No. 24. disturbed isomagnetic curves; Chart No. 25, isogonic curves for the United States (exclusive of Alaska) at the epoch 1890 (January); Chart No. 26, isogonic curves for Alaska and adjacent parts, with annual change of the declination, for 1890; Chart No. 27, magnetic meridians of the United States (exclusive of Alaska) and annual change of the declination for the epoch of 1890.
1890	8	199–241	Terrestrial magnetism.—Results from the magnetic observatory of the Coast and Geodetic Survey at Los Angeles, Cal., between the years 1882 and 1889. Part I, Results of the absolute measures of the direction and intensity of the earth's magnetic force.—Discussion and report by C. A. Schott, Assistant.
1890	9	243–457	Part II, Results of the differential measures of the magnetic declination, with hourly readings of the unifilar traces.—By Charles A, Schott, Assistant. (Nine illustrations.)
1890	......	211–214	Bulletin No. 20.—The magnetic observations made on Bering's first voyage to the coasts of Kamchatka and Eastern Asia in the years 1725 to 1730.—Discussion by C. A. Schott, Assistant.
1890	12	625–684	Determinations of gravity and the magnetic elements in connection with the U. S. Scientific Expedition to the west coast of Africa, 1889–1890.—A report by E. D. Preston, Assistant. (Eleven illustrations.)

ASTRONOMY.

Year.	Appendix.	Pages.	Subject and author.
1849	5	72–78	Mechanical record of astronomical observations.—O. M. Mitchel. Revolving disk; arrangement for recording differences of declination.
1851	9	137–145	Report on a new method of recording differences of north polar distances, or declination, by electro-magnetism.—O. M. Mitchel.
1854	40	122–127	Solar eclipse, May 26, 1854. Observations made at Brooklyn, Long Island, reported by E. Blunt; at Seaton station, Washington, D. C., by C. O. Boutelle; at Roslyn station, near Petersburg, Va., by L. F. Pourtales; Black Mountain station, Cal., by R. D. Cutts; Benicia, Cal., by Prof. James Nooney; Humboldt Bay, Cal., by G. Davidson, Assistant.
1855	45	278–286	Star catalogues.—C. A. Schott, Assistant. Comparison of star places given in Rümker's and the Twelve-Year Catalogues.—Table I, comparison of right ascensions; Table II, of north polar distances.
1860	21	229–275	Solar eclipse, July 18, 1860.—Prof. Stephen Alexander. Results of the expedition to Aulezavik Island, Labrador, to observe the total eclipse of the 18th of July, 1860; tabular comparison of chronometers; arrangement and programme; description of the telescopes employed; synopsis of the observations; times of contacts; same in local mean time (civil reckoning); other observations; reports from special parties; earth temperature (Aulezavik); atmospherical electricity; icebergs, mirage, etc.; triple rainbow; auroras; table of meteorological observations made during the hours corresponding to the eclipse at Aulezavik, from July 14 to July 23, and during the continuance of auroras from June 30 to August 6; observations with Arago's polariscope; report of photographers; changes of illumination; seamen's observations; winds; magnetic elements; longitude by chronometers.—[Sketch; 39.]—[Errata 239, 275: 1860, p. xx.]

A subject-index to the professional papers contained in the annual reports, etc.—Continued.

ASTRONOMY—Continued.

Year.	Appendix.	Pages.	Subject and author.
1860	2	275–292	Solar eclipse.—Lieut. J. M. Gilliss, U. S. N. On the results of observations made near Fort Steilacoom, W. T., on the solar eclipse of July 18, 1860; preliminary; table of meteorological observations on Muck Prairie; latitude observations; time observations; chronometer errors and rates; longitude; the eclipse; reports from special parties.
1861	16	182–195	Report upon the determination of the longitude of America and Europe from the solar eclipse of July 28, 1851.—By Benjamin Peirce, LL. D.
1861	17	196–221	Report of Professor Benjamin Peirce on an example for the determination of longitudes by occultations of the Pleiades.
1861	19	232–239	Solar eclipse of July, 1860.—A. D. Bache, Superintendent. Abstract of observations made at Gunstock Mountain, N. H.; (1) dispositions; (2) first contact; (3) positions of spots; I, table of observations, July 17; II, July 18, before; III, during; IV, after the eclipse; (4) occultation of spots; (5) last contact; (6) phenomena.—[Sketch 29.]—[Errata, 232: 1862, front leaf.]
1861	20	239–241	Solar eclipse of July, 1860.—C. A. Schott, Assistant. Abstract of observations made at the Coast Survey Office, Washington, D. C.; first contact; last contact; after the eclipse; heliographic position of the spots.
1861	21	241–242	Solar eclipse of July, 1860.—Dr. B. A. Gould, Assistant. Abstract of observations made at Cambridge, Mass.
1861	25	259–261	Solar spots.—C. A. Schott, Assistant. Abstract of observations made at the Coast Survey Office, Washington, D. C.; table from August, 1860, to December, 1861, and monthly relative numbers, compared with Wolf's revised numbers; spotless days.—[Sketch 29.]
1862	12	155, 156	On the computations of the occultations of the Pleiades for longitude.—Report by Prof. Benjamin Peirce, of Harvard.
1862	13	157, 158	Upon the Tables of the Moon used in the reduction of the Pleiades.—By Prof. Benjamin Peirce, of Harvard.
1862	....	15	Standard places of fundamental stars (first edition).—Dr. B. A. Gould, Assistant.
1862	21	231–232	Solar spots.—Report on observations made at the Coast Survey Office from January to August, 1862.—By C. A. Schott, Assistant.
1865	15	152–154	Report and tables on the declinations of standard time-stars.—Dr. B. A. Gould, Assistant.
1865	16	155–159	Report and tables on the positions and proper motions of the four polar stars.—Dr. B. A. Gould, Assistant.
1866	....	15	Standard places of fundamental stars (second edition).—Dr. B. A. Gould, Assistant.
1869	7	113–115	Local deflections of the zenith in the vicinity of Washington City.—C. A. Schott, Assistant.
1869	8	116–198	Solar eclipse, August 7, 1869. Reports of observations of the eclipse of the sun on August 7, 1869, made by parties of the Coast Survey at the following stations: Bristol, Tenn., in charge of R. D. Cutts; Shelbyville, Ky., J. Winlock and G. W. Dean; Springfield, Ill., C. A. Schott; Des Moines, Iowa, J. E. Hilgard; Kohklux, Chilkaht River, Alaska, G. Davidson.—General path of the eclipse; contacts; obscuration of solar spots; breaking of sun's limb by lunar asperities; effects of optical inaccuracies; totality; protuberances; corona; emergence; northern and southern limits of totality ascertained; spectroscopic observations; photographic records; reduction of micrometric photograph measures; deviation of photographed sun's outline from a circle, after corrections; computations of results.—[Sketches 24, 25, and 26.]—[Errata 165.]
1870	16	115–177	Reports of observations upon the solar eclipse of December 22, 1870; extent of the corona as indicated by the spectroscope, p. 150; nature of the coronal envelope and its relation to the sun, p. 152; constitution of the solar atmosphere, p. 153; suggestions with reference to the observation of future eclipses, pp. 154–158.

A subject-index to the professional papers contained in the annual reports, etc.—Continued.

ASTRONOMY—Continued.

Year.	Appendix.	Pages.	Subject and author.
1870	16	229	Report on the solar eclipse of December 22, 1870.—Prof. Benjamin Peirce, LL. D.—[From report for 1871.]
1871	13	176–179	Total solar eclipse, December 22, 1870.—G. W. Dean, Assistant. Abstract of the chronographic record.
1871	14	180–184	Total solar eclipse, December 22, 1870.—Prof. C. H. F. Peters.
1871	16	189–191	New form of mercurial horizon.—J. Homer Lane. Directions for setting up and using.
1872	8	75–172	Reports of the astronomical and meteorological observations made at Sherman, Wyo. T.—R. D. Cutts, Assistant, and Prof. Charles A. Young. Part I, Report of R. D. Cutts [Sketch No. 18 A]. Latitude and longitude of Sherman; terrestrial magnetism; meteorology; Table I, difference of reading of observers; Table II, daily means; diagram 1; Table III, hourly means; diagram 2; Table IV, hourly means; aneroid barometer; solar radiation; Table V, amount of solar radiation; Table VI, solar radiation; altitude of the sun; atmospheric electricity; diagram; Table VIII, altitude of the astronomical station; spirit level; barometer; Tables IX, X, XI; boiling-point apparatus; Table XII, temperature of boiling water at Sherman; Table XIII, height of Long's Peak, etc.; Sherman, its atmosphere and climate; meteorological journal.
		155	Part II, Report of Prof. C. A. Young. Spectrum of the chromosphere; catalogue of bright lines in the spectrum of the chromosphere, 1872; table showing the number of coincidences between the bright lines observed in the spectrum of the chromosphere and those in the spectrum of the chemical elements; spectra of sun spots; catalogue of lines affected in the spot-spectrum between B and *b*; solar eruptions and other disturbances.
1872	9	173–176	Astronomical observations on the Sierra Nevada.—George Davidson, Assistant. Description of the country adjacent to the station at Summit; the climate and opportunities for observing; the observations; Polaris, Saturn, Moon, etc.
1873	14	138–174	A list of stars for observations of latitude.
1873	15	175–180	Errata in the Heis Catalogue of Stars.
1874	10	131–133	Transit of Venus, 1769.—C. A. Schott, Assistant. Results of observations for determining positions occupied in Lower California and at Philadelphia.—[Sketch No. 22.]
1875	13	222–239	Transit of Venus, Japan, 1874.—George Davidson, Assistant. Station near Nagasaki, Japan; observers; telegraphic longitude work; details of observations of the Transit; photographic work; observations at great elevations.
1875	14	231–248	Transit of Venus, Chatham Island, 1874.—Edwin Smith, Assistant. Station; foundation; instruments; [Sketch No. 25]; observations; photography; day of transit; work after the transit; computations and results; latitude observations; mean places of stars observed for latitude; results for latitude; magnetic observations; declination; dip; horizontal intensity; results.
1876	7	83–129	A catalogue of stars for observations of latitude.
1878	6	81–87	Transit of Mercury, Summit Station, Central Pacific Railroad [Sketch No. 27].—B. A. Colonna, Assistant. First external and internal contacts; second internal and external contacts; extracts from record book of observations, by B. A. Colonna; diagram; observation of contacts, by J. F. Pratt, Assistant.
1878	7	88–91	Transit of Mercury, Washington, D. C.—C. A. Schott, Assistant. Observations by R. D. Cutts, William Eimbeck, and O. H. Tittmann, Assistants.
1882	20	463–468	The total solar eclipse of January 11, 1880, as observed at Mount Santa Lucia, California.—By George Davidson, Assistant. Selection of Mount Santa Lucia; height and topography of surrounding country; instrumental outfit; facilities afforded Prof. Frisby, of the U. S. Naval Observatory, and facilities afforded by the Southern Pacific Railroad and Mr. Newhall; examination of approaches to mountain; determination of latitude and time; plan of observing eclipse; instruments and observers; condition of atmosphere on day of

A subject-index to the professional papers contained in the annual reports, etc.—Continued.

ASTRONOMY—Continued.

Year.	Appendix.	Pages.	Subject and author.
			eclipse; steadiness of limb of Sun; observation of first contact; disappearance of the umbræ; sharpness of Sun's cusps; apparently doubled by atmospheric disturbance; duplication of cusp, shown by Fig. 1; difference in the darkness of sky adjacent to Sun's disk; sharpness of cusps 50 minutes after commencement; one hour after commencement limb of Moon steady enough to see lunar mountains near apparent right cusp, Fig. 2; irregularities of lunar outline; atmosphere slightly disturbed by cirrus clouds toward totality; long and narrow crescent of sunlight as totality rapidly approaches, illustrated by Fig. 3; no distortion from atmospheric disturbances; only slight shivering; cusps very sharp; last line of sunlight first broken by the lunar mountains; absence of "Bailey's beads;" colored glass used in observing contact; on account of small diameter of cone, the brightness of corona, and the effect of cirrus clouds, sky too bright to see any stars or small planets; study of rose-colored flames and first circle of bright light; Fig. 4, corona sketched; shape of brilliant rose-colored flames; brightness of first concentric ring of white light; second and fainter concentric ring; sketch of corona immediately after totality; agreement of outline and general features, as noted by different observers; rapid change in appearance of corona, as noted by some of the observers; third contact observed; shadow of total phase seen on ocean before totality; shade of retreating cone seen on sky after totality, but no shadow seen on the dark mountains; clouds interfere and fourth contact unsatisfactorily observed; table giving times of contacts, as noted by different observers; temperature and barometric readings; Jupiter and Mars seen before totality; no stars seen; limits of the southern line of totality; eclipse observed by Dr. Eisen, at Borden, on Southern Pacific Railroad; extract from his report, with sketch, Fig. 5; Mr. Moore, at San Rafael, sees irridescent colon at part of Sun first touched by Moon; eclipse of 1869, in Alaska, contrasted with eclipse of 1880, in California; confirmation of theory that "Bailey's beads," "ligament," and "black drop" are due to atmospheric disturbances; zodiacal light observed at Mount Santa Lucia; geographical position of station.—[Illustrations 51, 52.]
1882	21	469–502	A new reduction of La Caille's observations, made at the Cape of Good Hope between 1749 and 1757, and given in his "Astronomiæ Fundamenta," together with a comparison of the results with the "Bradley-Bessel" "Fundamenta;" also, a catalogue of the places of 150 stars south of declination −30°, for the epochs 1750 and 1830.—By C. R. Powalky, Ph. D. Prefatory note by J. E. Hilgard; preface; introduction; examples of observations with a sextant at Paris; Table I, right ascensions; Table II, declinations; Table III, declinations continued; Table III*a*, declinations, with sector, at Paris, continued; Table IV, declinations, with sextant at the Cape compared with La Caille in his "Astronomiæ Fundamenta;" Table IV*a*, sextant at the Cape; Table IV*b*, sector at the Cape; Table V, mean declination for 1750 (corrected); results compared; Table VI, catalogue of 150 fixed stars, south of 30° declination, from La Caille's observations at the Cape of Good Hope, in his "Astronomiæ Fundamenta" for 1750.0 and for 1830.0, without regard to proper motions; report on the preceding reduction of La Caille's observations by Prof. C. H. F. Peters.
1883	15	369–370	The transit of Mercury of November 7, 1881, as observed at Yolo Base, California.—By George Davidson and J. J. Gilbert, Assistants. Point of observation; instruments used; geographical position of station; first contact lost; observed time of second contact; estimated time when the planet was one diameter on sun's disk; appearance of planet when on face of the sun; observations of error of chronometer with sextant; observation of transit at Middle Base Camp; instruments and observer; geographical position of station; observed time when planet one fifth diameter on sun; observed time of second contact; error of watch from sextant observations; remarks; condition of atmosphere at time of transit; topography of surrounding country; sun's disk, at time of ingress, not sharp at first station; "black ligament," "black drop," etc., seen; not seen at second station; closeness of two observed times; atmospheric disturbances; similar disturbances of signals in the daytime observations of geodetic work; intense blackness of planet's disk; problematical planet Vulcan should have been seen if it existed; time and geographical positions determined by Mr. Hill.
1883	16	371–378	Observations of the transit of Venus of December 6, 1882, at Washington, D. C., at Tepusquet Station, California, and at Lehman's Ranch, Nevada.—Location of station at Washington; instruments and observers; first external contact; first internal contact; second internal contact; the last contact; error of chronometer, from Naval Observatory

A subject-index to the professional papers contained in the annual reports, etc.—Continued.

ASTRONOMY—Continued.

Year.	Appendix.	Pages.	Subject and author.
			time-ball.—Charles A. Schott, Assistant; J. G. Porter, Computer, Coast and Geodetic Survey. Observations by B. A. Colonna, Assistant; prefatory remarks; instruments for time and for observation; comparison of timepieces; first external contact; note; second interior contact; note; second exterior contact; note. Mr. P. A. Welker's observations of third and fourth contacts at station Tepusquet, Cal.; station; observer; instruments; outlines very sharp and distinct; observed times of third and fourth contacts; hourly rate of chronometer.—Reported by James S. Lawson, Assistant. Assistant Eimbeck's observations of third and fourth contacts at Lehman's Ranch, Nevada.—Geographical position of station; instrument used; atmospheric conditions; observed time of third and fourth contacts; chronometer used and its errors; method of observing; no "black drop" seen; contacts well observed; defective arrangement for screening down sun's excessive light; comparison of chronometers; Mr. Marr's results compared with Mr. Eimbeck's; no delay in the regular work of the Survey.—William Eimbeck, Assistant. Mr. Marr's observations of third and fourth contacts.—Instrument used; atmosphere; observed time of third contact; observed time of apparent middle of planet; observed time of fourth contact; appearance of sun and planet.—R. A. Marr, Aid.
1883	18	383–471	Field catalogue of 1278 time and circumpolar stars—mean places for 1885.0.—By George Davidson, Assistant.
1886	6	153	The solar (annular) eclipse of March 5, 1886.—Reported by George Davidson, Assistant. Prefatory letter; observations made at the Coast and Geodetic Survey station, Lafayette Park, San Francisco, Cal., and at the Davidson Observatory; observations of first and second contacts; instruments and observers.
1888	13	465–470	Differential method of computing the apparent places of stars for determinations of latitude.—By E. D. Preston, Assistant.
1889	....	151–155	Bulletin No. 14.—Approximate times of culminations and elongations and of the azimuths at elongation of Polaris for the years between 1889 and 1910.

MATHEMATICS.

Year.	Appendix.	Pages.	Subject and author.
1854	33	63–95	Computation of triangulation.—Comparison of the reduction of horizontal angles by the methods of "dependent directions" and of "dependent angular quantities" by the method of least squares.—A. D. Bache. [Sketch 58.]—[Errata, 65, 70, 72, 75, 78, 79, 91, 94: 1855, p. xix.] Adjustment of horizontal angles of a triangulation. Probable error of observation, derived from observations of horizontal angles at any single station and depending on directions.—C. A. Schott.
1854	41	131–138	Report containing directions and tables for the use of Peirce's criterion for the rejection of doubtful observations.—B. A. Gould. [Errata, p. 138.]
1855	40	255–264	Normal equations.—C. A. Schott. Solution of normal equations by indirect elimination.
1856	59	307–308	Probable error.—Article from "Astronomische Nachrichten, No. 1034," translated by C. A. Schott. Determination of the probable error of an observation by the differences of the observations from their arithmetical mean.
1860	36	361–391	Formulæ for computing latitudes, longitudes, and azimuths, with an example as used in the Coast Survey Office, and tables for each minute of latitude from 23° to 50°.
1860	37	392–396	Cauchy's interpolation formulæ; with remarks by C. A. Schott.
1864	13	116–119	Problem in geodesy.—Determining a position by angles observed from it on any number of stations. Solution of Gauss, with example, communicated by C. A. Schott.
1864	21	220–222	Trajectory of ricochet shots from a 15-inch Rodman gun; notes on.—C. A. Schott.

A subject-index to the professional papers contained in the annual reports, etc.—Continued.

MATHEMATICS—Continued.

Year.	Appendix.	Pages.	Subject and author.
1864	22	223	Ranges of shot from 15 and 20 inch guns, determination of, by C. A. Schott.
1869	14	235	Solution of the three-point problem, by determining the point of intersection of a side of the given triangle with a line from the opposite point to the unknown point.—A. Lindenkohl.
1870	21	200–224	On the theory of errors of observations.—C. S. Peirce.
1875	19	315–368	Formulæ and factors for the computation of geodetic latitudes, longitudes, and azimuths. (Errata, pp. 316, 317, 318, 367.) Fig. 1. L, M, Z, forms for primary and secondary triangulation, and inverse solution; tables of factors log A, log B, log C, log D, log E; table of correction to longitude for difference in arc and sine; values of log $\frac{1}{\cos \frac{1}{2} d\,L}$; table for referring values of coefficients A, B, C, D, E, from Bessel's to Clarke's ellipsoid; table of log F; auxiliary tables for converting arcs of the Bessel ellipsoid into arcs of the Clarke ellipsoid; formulæ and table for computing the spherical excess of a triangle; table of log *m*.
1876	6	81	A new system of Binary Arithmetic.—Benjamin Peirce.
1876	14	197–201	Note on the theory of the economy of research.—C. S. Peirce.
1881	....	26	General properties of the equations of steady motion.—By Thomas Craig.
1882	....	i–xiv 1–247	A Treatise on Projections. Part I—Mathematical Theory of Projections. Part II—Construction of Projections.—By Thomas Craig. [Treasury Department, Document No. 61, Coast and Geodetic Survey.]
1884	7	323–375	Formulæ and factors for the computation of geodetic latitudes, longitudes, and azimuths (third edition). Prefatory remarks; direct and indirect methods; Bessel's and Puissant's solutions; formulæ for dL, dM, and dZ, discussed and established; example of L, M, Z for primary triangulation; example of L, M, Z for subordinate triangulation; the inverse problem; L, M, Z, form for inverse solution; log factors A, B, C, D, and E, between latitudes 23° and 65°, based on the Clarke spheroid of 1866; table of corrections to longitude for differences in arc and sine; table of values of log $\frac{1}{\cos \frac{1}{2} d\,L}$; table of log F; formula and table for computing the spherical excess of triangles, based on the Clarke spheroid of 1866.
1885	15	503–508	Note on a device for abbreviating time reductions.—By Charles S. Peirce, Assistant.
1888	13	465–470	Differential method of computing the apparent places of stars for determinations of latitude.—By E. D. Preston, Assistant.
1890	13	685–687	On an approximate method of deducing probable error.—By C. H. Kummell, Computing Division. On the determination by least squares of the relation between two variables, etc.—By Prof. Mansfield Merriman, late Acting Assistant.

DRAWING, ENGRAVING, AND ELECTROTYPING.

1851	55	541–553	Electrotyping operations of the Coast Survey.—G. Mathiot. Adhesion of deposit to matrix; actions in the electrolytic solution; laboratory apparatus; manipulation.—[Sketch 58.]
1852	21	108–111	On lithographic-transfer printing.—Maj. I. I. Stevens, U. S. Engineers.
1853	36	90–93	Notes on lithography and lithographic transfer.—Lieut. E. B. Hunt, U. S. Engineers.
1854	31	54–57	On electrotype operations and chemiglyphic experiments.—G. Mathiot.
1854	56	193–201	Mathiot's self-sustaining battery.—G. Mathiot. Its principles and workings.—[Errata, pp. 194, 198; 1855, p. xix.]
1854	57	201–212	Art and practice of engraving.—Lieut. E. B. Hunt, U. S. Engineers. Coast Survey engraving; its office, organization, and history.—[Errata, p. 204; *see* Index of errata.]
1855	61	366–368	Galvanic experiment.—G. Mathiot. Time required to produce the maximum intensity of a voltaic current.

A subject-index to the professional papers contained in the annual reports, etc.—Continued.

DRAWING, ENGRAVING, AND ELECTROTYPING—Continued.

Year.	Appendix.	Pages.	Subject and author.
1855	62	369	Electrotype art.—G. Mathiot. Improved method for joining detached plates by electrotyping.
1855	63	370–373	Mathiot's branch-circuit galvanometer.—G. Mathiot. On a method of measuring galvanic currents of great quantity.
1856	62	316–317	Electrotypes.—G. Mathiot. On the result of experiments made in printing from thin plates.
1860	20	216–229	Topographical and hydrographical delineations.—H. L. Whiting, Assistant. On the contouring and reduction of maps; on the scale of shades, and on the application of photography in preparing details for the engraver; (1) generalization of contour and other natural features for reduction to 1-80,000 contour; salt marsh; sand beaches and sand hills; woods; fresh marsh; shore line; low water; (2) hydrographic reductions; (3) reductions by photography; (4) scale of shades; report of E. Hergesheimer, Assistant.
1860	40	398–399	Dividers for tidal curves. Description of form invented by J. R. Gilliss for graphical decomposition.—[Sketch 40.]
1861	15	180-181	Drawing paper. Results of experiments made on the relative expansion and contraction, under atmospheric changes, of parchment paper and backed antiquarian paper.—[Sketch 31.]
1862	27	255	Drawing paper tested with reference to expansion and contraction under atmospheric changes.
1863	24	206–207	Harrison globe lens —J. E. Hilgard, Assistant, in charge of the Office. On tests made at the Coast Survey Office.
1866	20	130–138	Electrotyping operations.—G. Mathiot. Historical; adhesion of deposit to matrix; time and expense of electrocasting; actions in the electrolytic solution; laboratory apparatus; manipulation.
1867	5	55–56	The pantograph; its use in engraving.—E. Hergesheimer, Assistant.—[Sketch 27.]
1875	6	87	Report upon electrotyping and photographing.—Dr. A. Zumbrock.
1879	11	191	Preparation of standard topographical drawings.—E. Hergesheimer, Assistant.—[Plates 42 to 49.]
1881	7	124–125	Type forms of topography, Columbia River.—By E. Hergesheimer, Assistant.—[Illustration 33.] (*See* Topography.)
1883	14	367–368	Report on the preparation of standard topographical drawings.—By E. Hergesheimer, Assistant.—[Illustrations 35–50.] (*See* Topography.)

MISCELLANEOUS.

Year.	Appendix.	Pages.	Subject and author.
1817	....	....	An account of pyrometric experiments made at Newark, N. J.—F. R. Hassler, Superintendent. [Transactions American Philosophical Society. New Series, Vol. I, pp. 210–227.]
1851 1866	10 19	145–160 120–130	Florida reefs, keys, and coast.—Prof. Louis Agassiz. Topography of Florida; mode of formation of the reef; animal life; the keys; coral reefs; ship channel; the mainland; coast survey; physical changes in the Gulf Stream: changes in ages to come.
1853	18	50, 51	Climate, soil, and general character of Florida Keys.—Lieut. James Totten, U. S. Army.
1853	35	89	Boiler incrustation.—J. Hewston, jr. Analysis of two specimens of deposit from the boiler of the Coast Survey steamer Hetzel.
1854	55	192	On the action of sea-water on metals.—J. E. Hilgard, Assistant On the action of sea water on metals used in the construction of instruments, and on magnetic needles; Phœnix disaster.—[Errata, p. 192, 5 from bottom, word 9, *read* presence.]

A subject-index to the professional papers contained in the annual reports, etc.—Continued.

MISCELLANEOUS—Continued.

Year.	Appendix.	Pages.	Subject and author.
1855	26	176–185	Descriptive report of localities on the western coast, from the north end of Rosario Strait, Washington Territory, to the southern boundary of California.—G. Davidson, Assistant.
1856	63	317–318	Analysis of sea water.—Chemical analysis of the water of New York Harbor.—Prof. Wolcott Gibbs.
1856	64	318–319	Analysis of sands from base-sites near east and south coasts of Florida.—Prof. Wolcott Gibbs. Examination of specimens of sand taken from the base-sites at Cape Florida and Cape Sable.
1856	70	335–340	Coast Survey steamer Hetzel.—Report on cause of boiler explosion.—[Sketch 67.]
1858	40	251–270	Foreign geodetic surveys.—Prof. W. P. Trowbridge, Assistant. Review showing their cost and progress, and other data, for comparison with the results of the United States Coast Survey; trigonometrical surveys of England, Ireland, and Scotland; hydrography of England; analysis of the report of the select committee appointed to consider the ordnance survey of Scotland, etc., 1856; France; India; Russia; Prussia; table of statistics of topographical maps in Europe; recapitulation; marine disasters—United States vessels, 1855, 1856, and 1857; imports, exports, tonnage, etc.; Great Britain, 1852 to 1855; Gulf of Mexico shipping; Florida reef.
1858	41	270–273	Progress of the United States Coast Survey.—Prof. W. P. Trowbridge, Assistant. Ratio of results for consecutive periods of twelve years.
1860	42	402–408	Geology of the coast of Labrador.—Notes by O. M. Lieber.
1862	25	241–248	Florida reef: its origin, growth, substructure, and chronology.—Capt. E. B. Hunt, U. S. Engineers.
1867	17	183–186	Geological and zoölogical researches; their relation and general interests in the development of coast features.—Prof. Louis Agassiz.
1870	19	182–189	On the phosphate beds of South Carolina.—Prof. N. S. Shaler.
1872	11	213–221	Voyage of the steamer Hassler from Boston to San Francisco.—L. F. Pourtales, Assistant.
1873	....	....	On the air contained in sea water.—Oscar Jacobsen.
1874	13	148–151	Economy in coal, as exemplified by the action of compound engines in the steamer Hassler.—Charles E. Emery. General description of the Hassler.
1876	13	192–196	On marine governors.—Charles E. Emery.
1879	12	192–198	Reconstruction of the dividing engine of the Coast and Geodetic Survey.—G. N. Saegmuller. Table of corrected screw readings for every degree: Table I, residual errors of graduation of theodolites Nos. 5, 118, 133; Table II.
1879	14	201	Internal constitution of the earth.—Benjamin Peirce.
1880	12	145–171	Blue clay of the Mississippi River.—George Little. List of authorities: geological history of the Mississippi River; southern drift; bluff or loess; loess or loam; the Mississippi bottoms; Port Hudson; water; soils I to V, analysis; summary; sections 1 to 44; formations, sections, and localities tabulated.—[Sketch No. 48.]
1880	....	....	On steady motion in an incompressible viscous fluid.—Thomas Craig.
1884	8	377–385	The run of the micrometer.—By George Davidson, Assistant.
1885	11	483–485	A plea for a light on St. Georges Bank.—By Henry Mitchell, Assistant. Exact position unknown in early times; position now accurately known, but unmarked: its position with reference to important surrounding points; benefit to be derived by European commerce and that of New York, New England, and New Brunswick from light-house; size of the fishing fleet on and crossing the Bank; importance of light and horn as a guide to this fleet; great loss of life and vessels under present conditions; shoal directly on shortest route from New York to British Channel, and near routes of ocean commerce of Massachusetts Bay and Bay of Fundy; fishing fleet delayed for want of signal; loss of largest privateer of 1812 (the Dart) on St. Georges; suggestion that memorial be erected in shape of lighthouse.

III.

BIBLIOGRAPHY (a); STATISTICS (b); OFFICIAL REPORTS OF EXPENDITURES AND OF PERSONS EMPLOYED (c); TABULAR STATEMENTS OF INFORMATION FURNISHED (d); ANNUAL REPORTS OF OFFICE OPERATIONS (e), AND NECROLOGY (f).

III*a*. BIBLIOGRAPHY.

U. S. COAST AND GEODETIC SURVEY.

Under this heading (III*a*) the titles of papers and documents dating from the inception of the Coast Survey until the year 1858 are taken for the most part from a collection of Coast Survey pamphlets bound together in one volume, and now in the possession of one of the compilers of this Appendix.

Year of publication.	Title.	Number of pages and size.	How printed or published.
1807	Circular of the Secretary of the Treasury (Albert Gallatin) in relation to a plan for executing the survey of the coast, addressed to Mr. Hassler, at Philadelphia, from the Treasury Department, March 25, 1807.	1, octavo.	Collection of pamphlets.
1843	Laws of 1807, 1832, and 1843 relating to the Survey of the Coast of the United States, with the plan of re-organization of 1843, and regulations by the Treasury Department.	19, octavo.	Gideon & Co., printers, Washington, D. C.
1844	Coast Survey.—Communication from the Secretary of the Treasury to the Committee of Ways and Means relative to the Coast Survey March 9, 1844.—Read and laid upon the table.	4, octavo.	Twenty-eighth Congress, first session. Doc. No. 168—Treasury Department.
1845	The Coast Survey of the United States.—From the American Journal of Science. Vol. XLIX.	24, octavo.	New Haven, Conn. Printed by B. L. Hamlen.
1845	The Coast Survey.—An article from the Princeton Review for April, 1845. By Joseph Henry, LL. D., Professor of Natural Philosophy in the College of New Jersey.	24, octavo.	Princeton. Printed by John P. Robinson, 1845.
1845	Report on re-organization of Coast Survey.—By the Secretary of the Treasury. Transmitting journal of Board appointed by the President to prepare plans for executing the work of the Survey. February 28, 1845.	32 pages.	Twenty-eighth Congress, second session. House Doc. No. 164—Vol. IV.
1847	The U. S. Coast Survey.—An article by C. F. Hoffman, editor of the Literary World.	4, quarto.	Literary World, New York, Sept. 11, 1847.
1847	Review of the annual report on the U. S. Coast Survey.—From the American Journal of Science and Arts. (Second series.)	11, octavo.	New Haven, Conn.
1848	Notes on the organization of the Coast Survey.	15, octavo.	
1848	Report on appropriations for Coast Survey.—By the Secretary of the Treasury. Response to Senate resolution. Statement of annual amount appropriated from commencement of Survey.	2.	Thirtieth Congress, second session. Senate Ex. Doc. No. 4—Vol. I.

Bibliography; statistics; official reports of expenditures, etc., etc.—Continued.

IIIa. BIBLIOGRAPHY—Continued.

U. S. COAST AND GEODETIC SURVEY—Continued.

Year of publication.	Title.	Number of pages and size.	How printed or published.
1849	Letter of the Secretary of the Treasury submitting a report in reply to a resolution of the Senate of December 27, 1848, relating to the expenditures and results of the U. S. Coast Survey. February 8, 1849.—Referred to the Committee on Finance and ordered to be printed.	111, octavo.	Thirtieth Congress, second session. Senate Ex. Doc. No. 26.
1849	Report in relation to steamers of the Revenue Marine transferred to the Coast Survey.	2, octavo.	Thirtieth Congress, second session. Report No. 137, House of Representatives.
1849	Message from the President of the United States communicating a report of the Secretary of the Treasury in relation to the number and cost of vessels and number of persons employed in the Survey of the Coast of the United States, and the amount of money received from the sale of maps and charts.	9, octavo.	Thirtieth Congress, second session. Senate Ex. Doc. No. 29.
1849	Report of the Secretary of the Treasury communicating a report from the Superintendent of the Coast Survey in relation to the survey of the coast of Florida. February 17, 1849.—Laid upon the table and ordered printed.	14, octavo.	Thirtieth Congress, second session. Senate Ex. Doc. No. 30.
1849	Speech of Mr. J. A. Pearce, of Maryland, on the subject of the Coast Survey of the United States, delivered in the Senate of the United States, on Saturday, February 17, 1849.	16, octavo.	Washington, D. C.—J. & G. S. Gideon, printers, 1849.
1849	Speech of Mr. Jefferson Davis, of Mississippi, on the subject of the Coast Survey of the United States, delivered in the Senate of the United States, Monday, February 19, 1849. As an appendix to the above-named speech, there were printed the following reports and memorials:	18, octavo.	J. & G. S. Gideon printers.
	Report of a committee of the American Academy of Arts and Sciences of Boston and Cambridge.	3, octavo.	
	Memorial of the Marine Society of Boston in relation to the Coast Survey, and memorial of the insurance companies of Boston in relation to the Coast Survey.	2, octavo.	
	Report of a committee of the Chamber of Commerce of New York, with resolutions of the same body on the U. S. Coast Survey, for transmission to Congress.	2, octavo.	
	Report of a committee of the American Philosophical Society of Philadelphia on the Coast Survey.		
	Report of a committee of the Franklin Institute of the State of Pennsylvania on the progress of the Survey of the Coast of the United States.	7, octavo.	
	Resolutions by the Board of Trade of Philadelphia relative to the Coast Survey; resolutions by underwriters, merchants, and owners of vessels of the city of Baltimore; memorial of the faculty of St. John's College, Maryland; letter from the faculty of the University of Virginia; resolutions of the Chamber of Commerce of Charleston, S. C., and resolutions of stockholders of the Mobile and Ohio Railroad—all in relation to the Coast Survey.	4, octavo.	
	NOTE.—The speeches, memorials, and resolutions above named led to the defeat of an effort made in the Senate in February, 1849 to reduce the appropriation for the Survey from $186 000 to $30,000, and to provide that it should be carried on exclusively by the Navy Department, under the direction of the President.		

Bibliography; statistics; official reports of expenditures, etc., etc.—Continued.

IIIa. BIBLIOGRAPHY—Continued.

U. S. COAST AND GEODETIC SURVEY—Continued.

Year of publication.	Title.	Number of pages and size.	How printed or published.
1849	Letter of the Secretary of the Treasury communicating a report by the Superintendent of the Coast Survey, dated December 26, 1848, on an application of the galvanic circuit to an astronomical clock and telegraph register in determining local differences of longitude, and in astronomical observations generally. January 6, 1849.—Laid on the table and ordered to to be printed.	13, octavo.	Thirtieth Congress, second session. House Ex Doc. No. 21.
1849	Survey of the Coast of the United States	18, octavo.	From Hunt's Merchants' Magazine and Commercial Review, February, 1849.
1849	Reply to an article in the February number of Hunt's Merchants' Magazine on the Coast Survey of the United States.—By Lieut. Charles Henry Davis, U. S. Navy.	15, octavo.	New York.—G. W. Wood, printer, 1849.
1849	Remarks by an Assistant in the Coast Survey on an article in the February number of Hunt's Merchants' Magazine on the Survey of the Coast of the United States.	14, octavo.	J. & G. S. Gideon, printers.
1849	The U. S Coast Survey. A reply	20, octavo.	Gideon, printer.
1850	Note from Prof. Bache to the editor of the Astronomical Journal, communicating an abstract of a report by Sears C. Walker, Assistant, U. S. Coast Survey, on recent telegraph operations for longitude, including experiments for wave time. Washington, February 1, 1850.	6, quarto.	The Astronomical Journal, Cambridge, Mass. April 20, 1850.
1851	Notes on the Gulf Stream.—By A. D. Bache, Superintendent U. S. Coast Survey; communicated by authority of the Treasury Department for Blunt's Memoir of the Atlantic Ocean. 1851.	16, octavo.	New York, E. & G. W. Blunt. 1851.
1851	The Coast Survey of the United States.—By Lieut. C. H. Davis, U. S. Navy. Reprinted from the American Almanac and Repository of Useful Knowledge for 1849.	28. octavo.	Washington. Gideon & Co., printers. 1851.
1851	Report of the Secretary of the Navy, in answer to a resolution of the Senate, relative to the transfer of the Survey of the Coast from the Treasury to the Navy Department. February 15, 1851.—Referred to the Committee on Finance and ordered to be printed.	14, octavo.	Thirty-first Congress, second session, Senate Ex. Doc. No. 35.
1851	Report of the Secretary of the Treasury, in answer to a resolution of the Senate, relative to the transfer of the Survey of the Coast from the Treasury to the Navy Department, February 15, 1851.—Referred to the Committee on Finance and ordered to be printed.	47, octavo.	Thirty-first Congress, second session, Senate Ex. Doc. No. 36.
1851	General rules for estimates, accounts, and classification of expenditures for the guidance of the chiefs of parties of the U. S. Coast Survey. 1851.	8, octavo.	Gideon & Co., printers.
1852	Notes on the use of the zenith telescope in determining latitudes in the Coast Survey by Talcott's method, and on the reduction of the observations.—By A. D. Bache, Superintendent U. S. Coast Survey. Reprinted from the American Journal of Science and Arts. Vol. XIV, second series,	16, octavo.	New Haven. Printed by B. L. Hamlen. 1852.
1854-1855	Consolidated alphabetical index of the ten Annual Coast Survey Reports from 1844 to 1853, inclusive.—Prepared by Lieut. E. B. Hunt, U. S Engineers, Assistant.	50, quarto.	Appendix to the Annual Report of the Superintendent for 1854.

Bibliography; statistics; official reports of expenditures, etc., etc.—Continued.

IIIa. BIBLIOGRAPHY—Continued.

U. S. COAST AND GEODETIC SURVEY—Continued.

Year of publication.	Title.	Number of pages and size.	How printed or published.
1854–1855	Consolidated index of sketches embraced in the Annual Coast Survey Reports from 1844 to 1853, inclusive.—Prepared by Lieut. E. B. Hunt, U. S. Engineers, Assistant.	6, quarto.	Appendix to the Annual Report of the Superintendent for 1854.
1855	An account of the measurement of two base lines in Florida. Section VI, U. S. Coast Survey.—By Fairman Rogers, Civil Engineer.	16, octavo.	From the Journal of the Franklin Institute, 1855.
1855	The U. S. Coast Survey. Its history, objects, organization, methods, and results.—From Putnam's Monthly of November, 1855.	14, octavo.	New York. Dix & Edwards. 1855.
1856	Report on an index of reference to memoirs and papers on subjects related to the Coast Survey operations.—By Lieut. E. B. Hunt, U. S. Corps of Engineers, Assistant, Coast Survey.	6, quarto.	Appendix No. 67. Report of Superintendent for 1856.
1856	On systematizing the abbreviations of titles of periodicals, transactions, etc.—By Lieut. E. B. Hunt, U. S. Corps of Engineers, Assistant, Coast Survey.	2, quarto.	Appendix No. 68. Report of Superintendent for 1856.
1858	Report of Lieut. E. B. Hunt, U. S. Engineers, Assistant in the Coast Survey, on the preparation of an index of scientific references.	11, quarto.	Appendix No. 51. Report of the Superintendent for 1857.
1858	Laws relating to the Survey of the Coast of the United States, with the plan of re-organization of 1843, and regulations by the Treasury Department.	25, octavo.	Public Printer. July, 1858.
1858	Report on the history and progress of the American Coast Survey up to the year 1858, by the Committee of Twenty appointed by the American Association for the Advancement of Science at the Montreal meeting, August, 1857.	88, octavo.	Printed by the American Association.
1858	Report of the Secretary of the Treasury, showing the amount expended and the progress made in the Coast Survey, and also in the standard weights and measures furnished to the several States and custom-houses, and their cost.	287, octavo.	Thirty-fifth Congress, second session, Vol. VI, Senate Report No. 6, part 2.
1858	Special report on the comparative progress and expenditure of the Coast Survey in different years. Foreign surveys, etc.	18, octavo.	Washington. Polkinhorn, printer. 1858.
1858	A popular account of the U. S. Coast Survey.	23, octavo.	From Appleton's New American Cyclopædia. 1858
1859	Review by Prof. W. P. Trowbridge, Assistant in the Coast Survey, relating to the origin, cost, and progress of foreign geodetic surveys, with other data for comparison with the results of the U. S. Coast Survey.	20, quarto.	Appendix No. 40, Report for 1858.
1859	Comparison of the cost and progress of the U. S. Coast Survey during the periods from 1832 to 1844, and from 1844 to 1856–'57.—By Prof. W. P. Trowbridge, Assistant in the Coast Survey.	4, quarto.	Appendix No. 41, Report for 1858.
1859	List of papers accompanying a special report made to the Treasury Department by Prof. A. D. Bache, Superintendent U. S. Coast Survey, in December, 1857. (See report Thirty-fifth Congress, second session, Vol. VI, Senate Report No. 6.)	1, quarto.	Appendix No. 42, Report for 1858.
1860	Report on Mississippi Sound by the Secretary of the Treasury, in answer to a resolution of the House. Memoir with charts prepared from the archives of the Coast Survey. By W. P. Trowbridge, April 6, 1860.	9, octavo.	Thirty-sixth Congress, first session, Ex. Doc. No. 58, Vol. IX.

Bibliography; statistics; official reports of expenditures, etc., etc.—Continued.

IIIa. BIBLIOGRAPHY—Continued.

U. S. COAST AND GEODETIC SURVEY—Continued.

Year of publication.	Title.	Number of pages and size.	How printed or published.
1860	Message on the navigation of the Harlem River. Containing report of A. D. Bache, Superintendent U. S. Coast Survey, relating to that river and to Spuyten Duyvil Creek, April 12, 1860.	6, octavo.	Thirty-sixth Congress, first session, Ex. Doc. No. 64, Vol. IX.
1860	The U. S. Coast Survey. Review of a report of the Secretary of the Treasury.	32, octavo.	From the North American Review for April, 1860.
1860	Lecture on the Gulf Stream. Prepared at the request of the American Association for the Advancement of Science, by A. D. Bache, Superintendent Coast Survey. Read at the Newport meeting, 1860.	17, octavo.	Published in the American Journal of Science and Arts, November, 1860.
1864–1866	Consolidated alphabetical index of the ten Annual Coast Survey Reports from 1854 to 1863, inclusive. Prepared by Subassistant F. F. Nes.	227–308, inclusive, quarto.	Appendix to the Report of the Superintendent for 1864.
1864–1866	Consolidated index of sketches embraced in the Annual Coast Survey Reports from 1854 to 1863, inclusive.	309–315, quarto.	Appendix to the Report of the Superintendent for 1864.
1865	What the Coast Survey has done for the war.—By Richard Meade Bache, Assistant, U. S. Coast Survey.	24, octavo.	Reprinted from the June and July numbers of the United Service Magazine. New York, 1865.
1868	Report on losses sustained by Coast Survey officers by the sinking of the steamer Arago in the Neuse River, North Carolina, July 21, 1868.	2, octavo.	Fortieth Congress, second session, Senate Report No. 181.
1869	Statutes relating to the Survey of the Coast of the United States, with the plan of re-organization of 1843 and regulations by the Treasury Department.	27, octavo.	Washington. Government Printing Office. 1869.
1871–1874	General index of professional and scientific papers contained in the U. S. Coast Survey Reports from 1851 to 1870.	193–209, quarto.	Appendix No. 17, Report for 1871.
1871–1874	Errata in the Coast Survey Reports from 1851 to 1870.	210–219, quarto.	Appendix No. 18, Report for 1871.
1871	On tides and tidal action in harbors.—By J. E. Hilgard, Assistant, U. S. Coast Survey.	17, octavo.	A lecture before the American Institute, New York, January 27, 1871. Reprinted with revisions in the Smithsonian Report for 1874.
1873	The Coast Survey. A lecture delivered before the New Haven Chamber of Commerce, March 26, 1873.—By R. Meade Bache, Assistant, U. S. Coast Survey.	19, octavo.	Published by request of the Chamber of Commerce.
1875	Account of a base-line measurement, three times repeated, in the U. S. Coast Survey.—By J. E. Hilgard, of Washington, D. C.	90–98, octavo.	From the proceedings of the American Association for the Advancement of Science, Detroit meeting, 1875.
1878	Surveys of the Territories. Letter from the Acting President of the National Academy of Sciences, transmitting a report on the surveys of the Territories.	27, octavo.	Forty-fifth Congress, third session. House Mis. Doc. No. 5.
	December 3, 1878.—Referred to the Committee on Appropriations and ordered to be printed.	....	Published in part, also, as Senate Mis. Doc. No. 9.
1878	Memorial from Civil Engineers asking an appropriation for continuing the triangulation of the Coast Survey in certain States.	1, octavo.	Forty-fifth Congress, second session. Senate Mis. Doc. No. 58—Vol. II.

Bibliography; statistics; official reports of expenditures, etc., etc.—Continued.

IIIa. BIBLIOGRAPHY—Continued.

U. S. COAST AND GEODETIC SURVEY—Continued.

Year of publication.	Title.	Number of pages and size.	How printed or published.
1879	Letter from the Secretary of War transmitting a copy of a communication from General Comstock, U. S. Engineers, relative to the duplication of the surveys of the Mississippi River by the Coast Survey. January 10, 1879.	3, octavo.	Forty-fifth Congress, third session. House Ex. Doc. No. 20—Vol. XI.
1879	Letter from the Secretary of the Treasury transmitting a communication from the Superintendent of the Coast and Geodetic Survey relative to the cost of certain classes of the work of the Survey. January 20, 1879.	4, octavo.	Forty-fifth Congress, third session. House Ex. Doc. No. 29—Vol. XI.
1879	Report by the Secretary of the Treasury relating to the organization of the Coast and Geodetic Survey.	6, octavo.	Forty-fifth Congress, third session. House Ex. Doc. No. 62—Vol. XVI.
1879	The Coast Survey. An article by Mrs. Martha J. Lamb.	507–521, octavo	Harper's New Monthly Magazine for March, 1879.
1880–1882	An attempt to solve the problem of the first landing place of Columbus in the New World.—By Capt. G. V. Fox, Assistant Secretary of the Navy, 1861–1866.	346–411, quarto.	Appendix No. 18, Coast and Geodetic Survey Report for 1880.
1881	Resolution instructing Committee on Finance of the Senate to make certain inquiries with reference to the organization of the Treasury Department, and to consider expediency of transferring certain bureaus of that Department, and among them the Coast and Geodetic Survey, to the Navy Department. January 12, 1881.	1, octavo.	Forty-sixth Congress, third session. Senate Mis. Doc. No. 16—Vol. I.
1881	Laws and regulations relating to the Coast and Geodetic Survey of the United States. Treasury Department, 1881. Document 110, Coast and Geodetic Survey.	42, octavo.	Washington, Government Printing Office, 1881.
1881	Laws of general application for the use of the U. S. Coast and Geodetic Survey. Treasury Department. Document 167, Coast and Geodetic Survey.	52, octavo.	Washington, Government Printing Office, 1881.
1881	Recent investigations of the Gulf Stream by the U. S. Coast and Geodetic Survey steamer Blake.—By Commander John R. Bartlett, U. S. N.	29–46, octavo.	Bulletin of American Geographical Society, New York, 1881—No. 1.
1881	The Basin of the Gulf of Mexico. Communication to National Academy of Sciences, November 18, 1880.—By J. E. Hilgard, M. N. A. S.	288–291, octavo.	Reprinted from the American Journal of Science, April, 1881—Vol. XXI.
1881–1883	General Index of Scientific Papers, Methods, and Results contained in the Appendices to the Annual Reports of the U. S. Coast and Geodetic Survey from 1845 to 1880, inclusive.—By C. H. Sinclair, Subassistant.	91–123, quarto.	Appendix No. 6—Report for 1881.
1882	The Gulf Stream. New data from the investigations of the U. S. Coast and Geodetic Survey steamer Blake.—By Commander John R. Bartlett, U. S. N. Naval Institute, Washington Branch. May, 1882.	221–231, octavo.	Reprinted from No. 20 of the proceedings of the U. S. Naval Institute.
1883	Letter of the Superintendent U. S. Coast and Geodetic Survey on the proposed transfer to the Navy Department. January 6, 1883.	8, octavo.	
1883–1884	Descriptive Catalogue of Publications relating to the Coast and Geodetic Survey and to Standard Measures.—Compiled by Edward Goodfellow, Assistant.	121–135, quarto.	Appendix No. 6—Report for 1883.

Bibliography; statistics; official reports of expenditures, etc., etc.—Continued.

IIIa. BIBLIOGRAPHY—Continued.

U. S. COAST AND GEODETIC SURVEY—Continued.

Year of publication.	Title.	Number of pages and size.	How printed or published.
1883	General considerations showing the impolicy of the adoption by Congress of the recommendation of the Secretary of the Navy to transfer the Coast and Geodetic Survey from the Treasury to the Navy Department.—By R. Meade Bache, Assistant.	1, quarto..	Philadelphia, 1883.
1884	The Late Attacks upon the Coast and Geodetic Survey.—By R. Meade Bache, Assistant. Reprinted from the October and November numbers of the United Service, 1884.	52, octavo.	Philadelphia. L. R. Hamersly & Co., No. 1510 Chestnut street, 1884.
1884	Notes on a proposed transfer of the Coast Survey to the Navy.—By Rear-Admiral Thornton A. Jenkins, U. S. N. 1884—June 5.	6, octavo.	Washington, D. C.
1884	U. S. Coast and Geodetic Survey. Historical Sketch.—Prepared by H. W. Blair, Assistant.	8, octavo.	Washington, D. C., June, 1884.
1884	Inquiry of the National Academy of Sciences concerning the operations of the Coast and Geodetic Survey. A statement by the Superintendent, addressed to Gen. M. C. Meigs, chairman of a committee of the National Academy of Sciences. September 19, 1884.	20, octavo.	Polkinhorn & Son, Printers, Washington, D. C.
1884	Coast and Geodetic Survey; article in the Supplement to the ninth edition of the Encyclopædia Britannica; Vol. II of Supplement.—By O. H. Tittmann, Assistant.	269–272, quarto.	American edition; Philadelphia and New York. Hubbard Bros., 1884.
1884	Brief account of the exhibit made by the Coast and Geodetic Survey at the Southern Exposition, Louisville, Kentucky, 1883.—By H. W. Blair, Assistant.	489–493.	Appendix No. 18. Report for 1884.
1886	Testimony before the Joint Commission to consider the present organizations of the Signal Service, Geological Survey, Coast and Geodetic Survey, and the Hydrographic Office of the Navy Department.	1–36 and 1–1104 octavo.	Forty-ninth Congress, first session. Senate Mis. Doc. No. 82.
1886	Report of the Joint Commission on the Signal Service, Geological Survey, Coast and Geodetic Survey, etc.	125, octavo.	Forty-ninth Congress, first session. Senate Report No. 1285—Parts I and II.
1886	Letters of Gen. W. F. Smith and Gen. H. G. Wright, relative to the topographical work of the U. S. Coast and Geodetic Survey. June 30 and July 1, 1886.	3, quarto.	Washington, 1886.
1887–1889	General index to the progress, sketches, and illustrations, maps and charts published in the Annual Reports of the U. S. Coast Survey and U. S. Coast and Geodetic Survey, from 1844 to 1885, inclusive.—Prepared by Edward Goodfellow, Assistant.	217–268, quarto.	Appendix No. 12. Report for 1887.
1888	U. S. Coast and Geodetic Survey. Historical compilation. A statement by the Superintendent on the basis of the Historical Sketch of 1884.	16, octavo.	Washington, 1888.
1887–1889	A Bibliography of Geodesy.—By J. Howard Gore, B. S., Ph. D., professor of mathematics, Columbian University, Acting Assistant, U. S. Coast and Geodetic Survey, etc.	313–512, quarto.	Appendix No. 16. Report for 1887.
1888	The U. S. Coast and Geodetic Survey.—By Henry P. Wells.	quarto.	Supplement to Harper's Weekly, Oct. 20, 1888.
1888	Short descriptions of articles forming the Coast and Geodetic Survey exhibit at the Centennial Exposition of the Ohio Valley and Central States, Cincinnati, Ohio, 1888.—Compiled and arranged by C. O. Boutelle, Assistant.	44, octavo.	Washington, D. C. Polkinhorn, Printer.

Bibliography; statistics; official reports of expenditures, etc., etc.—Continued.

III*a*. BIBLIOGRAPHY—Continued.

U. S. COAST AND GEODETIC SURVEY—Continued.

Year of publication.	Title.	Number of pages and size.	How printed or published.
1889-1890	Coast Survey.—An article by J. E. Hilgard, ex-Superintendent, in Johnson's (revised) Universal Cyclopædia, Vol. II.	123-126, quarto.	New York. A. J. Johnson & Co.
1889-1891	International Geodetic Association, ninth conference. Paris, 1889. Report of George Davidson, Assistant, U. S. Coast and Geodetic Survey. Delegate appointed by the President of the United States.	493-503, quarto.	Appendix 18, Report for 1889.
1890-1891	International Geodetic Association, ninth conference. Address of George Davidson, Assistant, U. S. Coast and Geodetic Survey. Delegate from the United States.	721-733.	Appendix 17, Report for 1890.
1890	Standing of Coast Survey officers during the Civil War. Referred to the House calendar May 26, 1890, and ordered to be printed. Report submitted by Mr. Spooner, from the Committee on Military Affairs.	2, octavo.	Fifty-first Congress, first session, House Report No. 2151.
1890	An act to define the standing of officers of the Coast Survey during the late Civil War. Passed the House of Representatives, September 17, 1890 In Senate, September 18, 1890, read twice and referred to the Committee on Military Affairs.	2, octavo.	Fifty-first Congress, first session, H. R. 6964.

III*b*. STATISTICS.

U. S. COAST AND GEODETIC SURVEY.

Under III*b*, Statistics, an enumeration will be made for each Annual Report published by the Survey, beginning with the Report for the year 1849, of the Appendices which contain results of the work in the form of tables of statistics. The Report for 1849 is the first in which a full tabular statement of statistics is given.

Year of Report.	Number of Appendix.	Title.	Number of pages and size.
1849		Results of the Coast Survey at different periods from 1807 to 1849	1, octavo.
		Results of the Coast Survey at different periods from—	
1850	39	1844 to 1850	2, octavo.
1851	5	1844 to 1851	3, octavo.
1852	4	1844 to 1852	1, quarto.
1854	7	1844 to 1854	1, quarto.
1855	7	1844 to 1855	1, quarto.
1856	7	1844 to 1856	1, quarto.
1857	7	Statistics of field and office work of the Coast Survey. (These statistics are arranged in a table, the first column of which shows the statistics previous to 1844; the next column gives those for 1844, and the following columns those for each subsequent year, the last being for 1856, and the final column one of totals.)	2, quarto.
		Statistics of field and office work of the U. S. Coast Survey during the years previous to 1844 and thence to and including—	
1858	8	1857	3, quarto.

Bibliography; statistics; official reports of expenditures, etc., etc.—Continued.

IIIb. STATISTICS—Continued.

U. S. COAST AND GEODETIC SURVEY—Continued.

Year of Report.	Number of Appendix.	Title.	Number of pages and size.
		Statistics of field and office work of the U. S. Coast Survey during the years previous to 1844 and thence to and including—Cont'd.	
1859	7	1858	3, quarto.
1860	7	1859	2, quarto.
1861	5	1860	3, quarto.
1862	3	1861	3, quarto.
1863	3	1862	4, quarto.
1864	3	1863	2, quarto.
1865	3	1864	2, quarto.
		Statistics of field and office work of the U. S. Coast Survey—	
1872	2	During the years previous to 1865, and thence to and including 1871	2, quarto.
1873	2	During the year 1872	2, quarto.
1874	2	During the year 1873	2, quarto.
1875	2	During the year 1874	2, quarto.
1876	2	To the close of the year 1875	2, quarto.
1877	2	To the close of the year 1876	2, quarto.
1878	2	To the close of the year 1877	2, quarto.
		Statistics of field and office work of the U. S. Coast and Geodetic Survey—	
1879	2	To the close of the year 1878	2, quarto.
1880	2	To the close of the year 1879	2, quarto.
1881	2	For the year ending December 31, 1881	2, quarto.
1882	2	For the eighteen months ending June 30, 1882	2, quarto.
		Statistics of field and office work of the U. S. Coast and Geodetic Survey for the year ending June 30—	
1883	2	1883	2, quarto.
1884	2	1884	2, quarto.
1885	2	1885	2, quarto.
1886	2	1886	2, quarto.
1887	2	1887	2, quarto.
1888	2	1888	2, quarto.
1889	2	1889	3, quarto.
1890	2	1890	3, quarto.

IIIc. OFFICIAL REPORTS OF EXPENDITURES AND OF PERSONS EMPLOYED.

U. S. COAST AND GEODETIC SURVEY.

Year of publication.	Title.	Number of pages and size.	How printed or published.
1842	Report by the Secretary of the Treasury of the expenditures for the survey of the United States coast. January 25, 1842.	8, octavo.	Twenty-seventh Congress, second session. House Doc. No. 57—Vol. II.
1843	Report of select committee on the result of an examination of the progress and expenditure of the Coast Survey. January, 1843.	103, octavo.	Twenty-seventh Congress, third session. House Report No. 43.
1843	Report of select committee. Additional information to that communicated in January by the same committee upon the progress and expenditures of the Coast Survey. February, 1843.	93, octavo.	Twenty-seventh Congress, third session. House Report No. 170.

Bibliography: statistics; official reports of expenditures, etc., etc.—Continued.

IIIc. OFFICIAL REPORTS OF EXPENDITURES AND OF PERSONS EMPLOYED—Continued.

U. S. COAST AND GEODETIC SURVEY—Continued.

Year of publication.	Title.	Number of pages and size.	How printed or published.
1848	Report by the Secretary of the Treasury on appropriations for the Coast Survey. December 22, 1848.	2, octavo.	Thirtieth Congress, second session. Senate Ex Doc. No. 4.
1849	Report of Secretary of the Treasury regarding Coast Survey expenditures and results. February 7, 1849.	111, octavo.	Thirtieth Congress, second session. Senate Ex. Doc. No. 26—Vol. III.
1849	Report of Secretary of the Treasury of number and cost of vessels and number of men employed in survey of United States coast. February 9, 1849.	9, octavo.	Thirtieth Congress, second session. Senate Ex. Doc. No. 29—Vol. III.
1853	Secretary of the Treasury submits report of Superintendent of Coast Survey showing number and names of persons employed in Coast Survey during year ending June 30, 1853, their compensation and service, with expenditures made under his direction. December 25, 1853.	16, octavo.	Thirty-third Congress, first session. Senate Doc. No. 11—Vol. IV.
1854	Secretary of the Treasury, transmits reports showing disbursements in behalf of the Coast Survey. December 27, 1854.	10, octavo.	Thirty-third Congress, second session. House Ex. Doc. No. 23—Vol. V.
1856	Letter of Secretary of the Treasury transmitting report of number and names of persons employed in the Coast Survey and expenditures made during the year 1854-'55. December 22, 1856.	12, octavo.	Thirty-fourth Congress, first session. House Ex. Doc. No. 44—Vol. IX.
1858	Secretary of the Treasury transmits list of persons employed in Coast Survey and expenditures for year ending June 30, 1857. January 15, 1858.	12, octavo.	Thirty-fifth Congress, first session. House Ex. Doc. No. 20—Vol. III.
1858	Secretary of the Treasury reports amount expended and progress made in the Coast Survey, and also the standard weights and measures furnished the several States and custom-houses, and their cost. December 16, 1858.	287, octavo.	Thirty-fifth Congress, second session. Senate Report No. 6—Part 2, Vol. VI.
1859	Report by Secretary of the Treasury of names and salaries of persons employed on the Coast Survey. January 7, 1859.	13, octavo.	Thirty-fifth Congress, second session. House Ex. Doc. No. 29—Vol. V.
1860	Report by Secretary of the Treasury transmitting list of the number and names of persons employed on the Coast Survey, amount of compensation, etc. December 24, 1860.	10, octavo.	Thirty-sixth Congress, second session. Ex. Doc. No. 15—Vol. VI.
1862	Report by Secretary of the Treasury of expenditures on account of the Coast Survey for the year ending June 30, 1861, list of persons employed, salaries, etc. March 6, 1862.	79, octavo.	Thirty-seventh Congress, second session. House Ex. Doc. No. 68—Vol. V.
1862	Report by Secretary of the Treasury transmitting list of the number and names of persons employed in the Coast Survey and expenditures during the year ending June 30, 1861. March 25, 1862.	11, octavo.	Thirty seventh Congress, second session. House Ex. Doc. No. 83—Vol. VII.
1863	Report by Secretary of the Treasury transmitting statement showing number and names of persons employed in the Coast Survey during the fiscal year ending June 30, 1863, amount of their compensation, and time of employment, with a statement of all expenditures made during the year. December 16, 1863.	11, octavo.	Thirty-eighth Congress, first session. House Ex. Doc. No. 13—Vol. VII.

Bibliography; statistics; official reports of expenditures, etc., etc.—Continued.

IIIc. OFFICIAL REPORTS OF EXPENDITURES AND OF PERSONS EMPLOYED—Continued.

U. S. COAST AND GEODETIC SURVEY—Continued.

Year of publication.	Title.	Number of pages and size.	How printed or published.
1864	Report of Secretary of the Treasury transmitting list of employés, with compensations and statement of expenditures of Coast Survey for fiscal year ending June 30, 1864. December 21, 1864.	9, octavo.	Thirty-eighth Congress, second session. House Ex. Doc. No. 13, Vol. VIII.
1866	Report of Secretary of Treasury, transmitting a statement of employés in the Coast Survey during the year ending June 30, 1865.	9, octavo.	Thirty-ninth Congress, first session. House Ex. Doc. No. 24, Vol. VII.
1866	Report by Secretary of the Treasury transmitting list of employés of Coast Survey with compensations, etc., for the fiscal year ending June 30, 1886. December 15, 1866.	10, octavo.	Thirty-ninth Congress, second session. House Ex. Doc. No. 15, Vol. VI.
1868	Report by Secretary of the Treasury on expenses of the Coast Survey for the year ending June 30, 1867. May 8, 1868.	9, octavo.	Fortieth Congress, second session. House Ex. Doc. No. 286, Vol. XVII.
1870	Report by Secretary of the Treasury transmitting list of employés, with compensations, and statement of expenditures of Coast Survey for fiscal year ending June 30, 1869. January 22, 1870.	8, octavo.	Forty-first Congress, second session. House Ex. Doc. No. 75, Vol. VI.
1871	Report by Secretary of the Treasury transmitting list of employés of the Coast Survey, with compensations, during fiscal year ending June 30, 1870. February 25, 1871.	9, octavo.	Forty-first Congress, third session. House Ex. Doc. No. 142—Vol. XII.
1874	Report of Secretary of the Treasury transmitting list of Coast Survey employés for year ending June 30, 1874. December 23, 1874.	8, octavo.	Forty-third Congress, second session. House Ex. Doc. No. 71, Vol. XII.
1879	Report by Secretary of the Treasury of expenditures on account of the Coast Survey for the fiscal year ending June 30, 1878. January 28, 1879.	7, octavo.	Forty-fifth Congress, third session. House Ex. Doc. No. 40, Vol. XVI.
1880	Report by Secretary of the Treasury transmitting a report of expenditures of the Coast and Geodetic Survey for the year ending June 30, 1879. March 26, 1880.	7, octavo.	Forty-sixth Congress, second session. House Ex. Doc. No. 68, Vol. XXIV.
1881	Report by Secretary of the Treasury transmitting a report of the expenditures of the Coast and Geodetic Survey for the year ending June 30, 1880. January 31, 1881.	7, octavo.	Forty-sixth Congress, third session. House Ex. Doc. No. 64, Vol. XVIII.
1882	Brief report of the Superintendent of the Coast and Geodetic Survey, containing statement of expenditures for the fiscal year ending with June 30, 1882. December 2, 1882.	18, octavo.	Treasury Department. Doc. No. 364.
1884	Letter from Secretary of the Treasury transmitting statement of expenditures of Coast and Geodetic Survey for the fiscal year ending June 30, 1883. January 22, 1884.	8, octavo.	Forty-eighth Congress, first session. House Ex. Doc. No. 63.
1884	Letter from Secretary of the Treasury transmitting statement of expenditures of Coast and Geodetic Survey for the fiscal year ending June 30, 1884. December 18, 1884.	8, octavo.	Forty-eighth Congress, second session. House Ex. Doc. No. 52.
1886	Letter from Secretary of the Treasury transmitting statement of expenditures of the Coast and Geodetic Survey for the fiscal year ending June 30, 1885. January 9, 1886.	30, octavo.	Forty-ninth Congress, first session. House Ex. Doc. No. 32.
1887	Letter from Secretary of the Treasury transmitting statement of expenditures of Coast and Geodetic Survey for fiscal year ending June 30, 1886. February 4, 1887.	27, octavo.	Forty-ninth Congress, second session. House Ex. Doc. No. 149.

Bibliography; statistics; official reports of expenditures, etc., etc.—Continued.

IIIc. OFFICIAL REPORTS OF EXPENDITURES AND OF PERSONS EMPLOYED—Continued.

U. S. COAST AND GEODETIC SURVEY—Continued.

Year of publication.	Title.	Number of pages and size.	How printed or published.
1888	Letter from Secretary of the Treasury transmitting statement of expenditures of Coast and Geodetic Survey for fiscal year ending June 30, 1887. February 11, 1888.	29, octavo.	Fiftieth Congress, first session. House Ex. Doc. No. 154.
1889	Letter from Secretary of the Treasury transmitting statement of expenditures of Coast and Geodetic Survey for fiscal year ending June 30, 1888. January 2, 1889.	30, octavo.	Fiftieth Congress, second session. House Ex. Doc. No. 53.
1890	Letter from Secretary of the Treasury transmitting statement of expenditures of Coast and Geodetic Survey for fiscal year ending June 30, 1889. January 2, 1890.	31, octavo.	Fifty-first Congress, first session. House Ex. Doc. No. 30.
1891	Letter from Secretary of the Treasury transmitting statement of expenditures of Coast and Geodetic Survey for fiscal year ending June 30, 1890. February 26, 1891.	28, octavo.	Fifty-first Congress, second session. House Ex. Doc. No. 278.

III*d*. TABULAR STATEMENTS OF INFORMATION FURNISHED.

U. S. COAST AND GEODETIC SURVEY.

Tabular statements of information furnished by the Survey in response to official calls, or in compliance with unofficial requests, under the regulations of the Treasury Department, will be found in the annual reports, as follows:

Year of report.	No. of appendix.	Pages.	Year of report.	No. of appendix.	Pages.	Year of report.	No. of appendix.	Pages.	Year of report.	No. of appendix.	Pages.
1852	7	83, 84	1862	2	74, 75	1872	3	63, 64	1882	3	79–84
1853	6	12, 13	1863	2	67–69	1873	3	76, 77	1883	3	87–92
1854	5	11, 12	1864	2	44–46	1874	3	57, 58	1884	3	97–102
1855	5	115, 116	1865	2	41, 42	1875	3	81, 82	1885	3	89–93
1856	5	104–106	1866	2	32	1876	3	75, 76	1886	3	107–113
1857	5	135, 136	1867	2	52	1877	3	78, 79	1887	3	105–111
1858	6	134, 135	1868	2	47	1878	3	75, 76	1888	3	107–111
1859	6	118, 119	1869	2	71	1879	3	85–87	1889	3	115–119
1860	6	117	1870	2	59–62	1880	3	70–72	1890	3	119–125
1861	4	85, 86	1871	2	78, 79	1881	3	75–80			

III*e*. ANNUAL REPORTS OF OFFICE OPERATIONS.

U. S. COAST AND GEODETIC SURVEY.

In the earlier Reports of the Coast Survey statements of progress made in office operations will generally be found following the abstracts of reports of field work, attention being called also to office work of special interest or importance in the introductory portions of the Reports.

This will be found to apply to the Annual Reports from 1844 to 1855, inclusive.

In the Reports from 1856 to 1864, inclusive, in addition to the notices of office operations in the body of each Report, there are Appendices which contain reports from the Chiefs of the Divisions of the Office, or, in some cases, the complete reports of the Assistant in charge of the Office, and of the Chiefs of Divisions. (See list of Contents of Appendices preceding Alphabetical Index.)

The publication of the annual reports of the Assistant in charge of the Office, and of the Chiefs of the Office Divisions, was discontinued during the years 1865 to 1880, inclusive, and the references to office operations were made in the same manner as those in the Annual Reports of the Survey from 1844 to 1855, inclusive, these references being supplemented by Appendices giving lists of drawings or engravings of charts in progress or completed, and by Appendices detailing the field and office work relating to tides.

In the Annual Report for 1881 the reports made by the Chiefs of the Computing, Tidal, Drawing, Engraving, and Hydrographic Divisions of the Office were printed in full; in the Report for 1882 these reports were published as Appendix No. 6; in the Annual Reports of the Survey from 1883 to 1889, inclusive, the annual reports of the Assistant in charge of Office and Topography, and of the Hydrographic Inspector, appear as Appendices Nos. 4 and 5; in the Annual Report for 1890, Appendix No. 4 contains the annual report of the Assistant in charge of the Office; Appendix No. 5 the annual report of the Hydrographic Inspector; Appendix No. 6 the annual report of the Disbursing Agent, and Appendix No. 7 the annual report of the Assistant in charge of the Office of Weights and Measures.

It has not been deemed advisable to add to the bulk of this Descriptive Catalogue by extended lists of these Office reports, embodying as they do much matter relating to routine operations and details of value chiefly for official reference.

III*f*. NECROLOGY. 1844 TO 1890.

U. S. COAST AND GEODETIC SURVEY.

Under III*f* will be found in alphabetical order the names of those officers and employés of the Survey who have died in its service, and with regard to whom memorial meetings were held or obituary notices issued.

Name and grade.	Reference to in Annual Report, or date of obituary notice.	Pages.
Allison, Richard, Passed Midshipman and Acting Master, U. S. N.	1847	45, 81, 82.
Bache, Alexander Dallas, Superintendent, 1844–1867	1867	330–334.
Bache, Charles M., Assistant	Apr. 21, 1890	
Bache, George M., Lieutenant U. S. N., Assistant, U. S. Coast Survey	1846	23, 62, 68.
Bache, Henry Wood, Subassistant	1879	10, 11.
Baker, Woods, Assistant	1852	5, 67, 132.
Barker, John R., Draughtsman and Artist	1884	16.
Barnard, Henry S., Engraver	1875	10.
Bissell, George W., Hydrographic Aid	1871	15
Blair, Henry Wayne, Assistant	1885	73, 76, 97, 98, 113.
Blunt, Edmund, Assistant	1866	8.
Boutelle, Charles Otis, Assistant	1890	84.
	June 25, 1890	
Cordell, Edward, Assistant	1870	8, 9.
Cutts, Richard D., Assistant	Dec. 15, 1883	
In charge of the Office	1884	14, 15.
Dankworth, F., Engraver	1859	32.
De Koven, William, Passed Midshipman, U. S. N	1851	533.
Dickins, Hugo L., Assistant	1844	18
Diggs, John H., Messenger	1871	15, 16.
Dorr, Frederick William, Assistant	Dec. 24, 1877	
Drinkard, C. L., Clerk	1881	55, 56, 64.
Duer, John K., Lieutenant U. S. N., Assistant, U. S. Coast Survey	1859	32.
Fairfax, Wilson M. C., Assistant	1860	30
Farley, John, Assistant	1874	16.
	Aug. 3, 1874	
Farquhar, George, Hydrographic Draughtsman	1880	40
Fauntleroy, E. H., Aid	1860	31.
Fauntleroy, R. H., Assistant	1850	47, 116, 117.
Fendall, Clarence, Subassistant	1868	8
Foster, James, Passed Midshipman, U. S. N.	1847	17.
Gerdes, Ferdinand H., Assistant	1884	15, 16.
Gilbert, Samuel A., Assistant	1868	7, 8.
Gilbert, Wyllys S., Subassistant	1862	19.
Gluck, John B., Assistant	1852	5, 28, 131.

Bibliography; statistics; official reports of expenditures, etc., etc.—Continued.

III*f*. NECROLOGY—Continued.

U. S. COAST AND GEODETIC SURVEY—Continued.

Name and grade.	Reference to in Annual Report, or date of obituary notice.	Pages.
Harding, William W., Subassistant	1871	15.
Harrison, A. M., Assistant	1881	9.
	Feb. 2, 1881	
Hassler, J. J. S., Assistant	1858	42.
Hein, Samuel, Disbursing Agent, 1844–1877; Librarian, 1877–1885	1886	118.
Hein, Harry S., Clerk	1871	15.
Hergesheimer, Edwin, Assistant, and Chief of the Drawing Division, U. S. Coast and Geodetic Survey Office	1889	96, 123.
Hering, M. O., Aid	1861	23.
Hoover, John T., Chief of the Miscellaneous Division, U. S. Coast and Geodetic Survey Office	1878	10, 63.
Hough, S. J., Aid	1857	83.
Hosmer, Charles, Assistant	1888	22.
Humphries, G. E., Aid	1857	43.
Hunt, E. B., Maj., U. S. Engineers, Assistant	1863	17, 18.
Hutchinson, Henry T., Sailing Master	1879	42.
Johnstone, M. T., in charge of Map Room	1866	9.
Karcher, Louis, Draughtsman	1886	118.
Kincheloe, Julius, Subassistant	1867	11.
Knight, John, Engraver	1875	10.
Kondrup, John C., Engraver	1875	10.
Mapes, W. B., Acting Aid	1886	57.
Mapes, W. H., Inspecting Engineer	1879	12.
McArthur, Wm. P., Lieut., U. S. N., Assistant, Coast Survey	1851	82, 509-511.
McClery, M. J., Draughtsman	1866	8, 9.
McCoy, Hazzard, Mail Messenger	1886	118.
McDonnell, Thomas, in charge of Map Room	1882	15.
Nes, Frederick F., Assistant	July 8, 1879	
Oltmanns, John G., Assistant	1870	9.
O'Sullivan, T. J., Draughtsman, in charge of Drawing Division	1886	118.
Over, Frank, Assistant Electrotypist	1886	118.
Palmer, William R., Maj., U. S. Topographical Engineers, Assistant in charge of the Coast Survey Office 1858 to 1862	1862	19, 431, 432.
Patterson, Carlile P., Superintendent, 1874–1881	Aug. 17, 1881	22.
	1882	14, 15, 559–563.
Patterson, W. P., Watchman	1868	8.
Pearl, Arthur F., Hydrographic Aid	1871	15.
Peirce, Benjamin, Superintendent, 1867–1874	Oct. 11, 1880	
Consulting Geometer, 1874–1880	1881	8, 9.
Pleasants, W. H., Engineer	1879	44.
Rumpf, Gottlieb, Computer	1882	63, 95.
Ruth, Joseph S., Assistant	1852	6, 51, 52, 132, 133.
Sands, William F., Hydrographic Aid	1862	20.
Seib, John, Assistant	1860	30.
Sengteller, A., Engraver	1884	16.
Sengteller, Louis A., Assistant	1889	70.
Smead, John R., Capt., Fifth U. S. Artillery	1862	19, 434.
Stevens, Isaac I., Brig. Gen., U. S. Volunteers, Assistant in charge of the Coast Survey Office 1849 to 1853	1862	19, 432, 433.
Stewart, Gordon A., Keeper of Archives	1882	16.

Bibliography; statistics; official reports of expenditures, etc., etc.—Continued.

III*f*. NECROLOGY—Continued.

U. S. COAST AND GEODETIC SURVEY—Continued.

Name and grade.	Reference to in Annual Report, or date of obituary notice.	Pages.
Taney, Edmund L., Subassistant	May 10, 1890	
Terrill, William R., Brig. Gen., U. S. Volunteers	1862	19.
Terry, Carlisle, jr., Subassistant	1887	62.
	Mar. 14, 1887	
Thompson, A. W., Aid	1861	23.
Throop, J. V. N., Engraver	1860	30.
Totten, Joseph Swift, Lieut., U. S. Artillery, Assistant	1853	15, 167, 168.
Wadsworth, Alexander S., Assistant	1862	19.
Walker, Sears C., Assistant	1853	15, 166, 167.
Waters, Richard, Fireman	1886	118.
West, Benjamin F., Subassistant	1853	15, 168, 169.
Wharton, Edward, Engraving Division	1868	8.
Whyte, Joseph, Clerk	1858	42.
Winlock, Joseph, Director of Harvard College Observatory and Astronomer for the Coast Survey	1875	10.
Würdemann, Gustavus, Tidal Observer	1859	32.
Yeatman, A., Master Carpenter	1884	16.

IV.

LIST OF TIDE TABLES FROM THE DATE OF EARLIEST PUBLICATION IN THE SURVEY TO THE YEAR 1890.

U. S. COAST AND GEODETIC SURVEY.

Year of publication.	Description.	Number of pages and size.	Mode of publication.
1854	Tide tables for the United States; prepared from the Coast Survey observations by A. D. Bache, Superintendent.	4, quarto.	Appendix No. 26, Report for 1853.
1855	Tide tables for the coast of the United States.	10, quarto.	Appendix No. 51, Report for 1854.
1856	Tide tables for the use of navigators; prepared from the Coast Survey observations by A. D. Bache, Superintendent.	12, quarto.	Appendix No. 53, Report for 1855.
1856	......do	14, quarto.	Appendix No. 17, Report for 1856.
1858	......do	21, quarto.	Appendix No. 20, Report for 1857.
1859	......do	22, quarto.	Appendix No. 43, Report for 1858.
1860	......do	32, quarto.	Appendix No. 14, Report for 1859.
1861	......do	34, quarto.	Appendix No. 16, Report for 1860.
1862	......do	34, quarto.	Appendix No. 9, Report for 1861.
1864	......do	34, quarto.	Appendix No. 8, Report for 1862.
1864	......do	34, quarto.	Appendix No. 12, Report for 1863.
1866	......do	33, quarto.	Appendix No. 8, Report for 1864.
1866	Tide tables for the Atlantic coast of the United States for the year 1867.	101, 12mo.	Pamphlet [Government Printing Office].
1866	Tide tables for the Pacific coast of the United States for the year 1867.	32, 12mo.	Do.
1867	Tide tables for the Atlantic coast of the United States for the year 1868.	109, 12mo.	Do.
1867	Tide tables for the Pacific coast of the United States for the year 1868.	58, 12mo.	Do.
1868	Tide tables for the Atlantic coast of the United States for the year 1869.	110, 12mo.	Do.
1868	Tide tables for the Pacific coast of the United States for the year 1869.	58, 12mo.	Do.
1869	Tide tables for the Atlantic coast of the United States for the year 1870.	111, 12mo	Do.
1869	Tide tables for the Pacific coast of the United States for the year 1870.	59. 12mo.	Do.
1870	Tide tables for the Atlantic coast of the United States for the year 1871.	112, 12mo	Do.
1870	Tide tables for the Pacific coast of the United States for the year 1871.	59, 12mo.	Do.
1871	Tide tables for the Atlantic coast of the United States for the year 1872.	119, 12mo.	Do.
1871	Tide tables for the Pacific coast of the United States for the year 1872.	59, 12mo.	Do.
1872	Tide tables for the Atlantic coast of the United States for the year 1873.	121, 12mo.	Do.
1872	Tide tables for the Pacific coast of the United States for the year 1873.	60, 12mo.	Do.
1873	Tide tables for the Atlantic coast of the United States for the year 1874.	122, 12mo.	Do.

List of tide tables from the date of earliest publication, etc.—Continued.

U. S. COAST AND GEODETIC SURVEY—Continued.

Year of publication.	Description.	Number of pages and size.	Mode of publication.
1873	Tide tables for the Pacific coast of the United States for the year 1874.	60, 12mo,	Pamphlet [Government Printing Office].
1874	Tide tables for the Atlantic coast of the United States for the year 1875.	122, 12mo.	Do.
1874	Tide tables for the Pacific coast of the United States for the year 1875.	61, 12mo.	Do.
1875	Tide tables for the Atlantic coast of the United States for the year 1876.	109, 12mo.	Do.
1875	Tide tables for the Pacific coast of the United States for the year 1876.	61, 12mo.	Do.
1876	Tide tables for the Atlantic coast of the United States for the year 1877.	124, 12mo.	Do.
1876	Tide tables for the Pacific coast of the United States for the year 1877.	61, 12mo.	Do.
1877	Tide tables for the Atlantic coast of the United States for the year 1878.	124, 12mo.	Do.
1877	Tide tables for the Pacific coast of the United States for the year 1878.	61, 12mo.	Do.
1878	Tide tables for the Atlantic coast of the United States for the year 1879.	128, 12mo.	Do.
1878	Tide tables for the Pacific coast of the United States for the year 1879.	65, 12mo.	Do.
1879	Tide tables for the Atlantic coast of the United States for the year 1880.	129, 12mo.	Do.
1879	Tide tables for the Pacific coast of the United States for the year 1880.	65, 12mo.	Do.
1880	Tide tables for the Atlantic coast of the United States for the year 1881.	129, 12mo.	Do.
1880	Tide tables for the Pacific coast of the United States for the year 1881.	65, 12mo.	Do.
1881	Tide tables for the Atlantic coast of the United States for the year 1882.	130. 12mo.	Do.
1881	Tide tables for the Pacific coast of the United States for the year 1882.	65, 12mo.	Do.
1882	Tide tables for the Atlantic coast of the United States for the year 1883.	130, 12mo.	Do.
1882	Tide tables for the Pacific coast of the United States for the year 1883.	66, 12mo.	Do.
1883	Tide tables for the Atlantic coast of the United States for the year 1884.	136, 12mo.	Do.
1883	Tide tables for the Pacific coast of the United States for the year 1884.	66, 12mo,	Do.
1884	Tide tables for the Atlantic coast of the United States for the year 1885.	136, 12mo.	Do.
1884	Tide tables for the Pacific coast of the United States for the year 1885.	66, 12mo.	Do.
1885	Tide tables for the Atlantic coast of the United States for the year 1886.	157, 12mo.	Do.
1885	Tide tables for the Pacific coast of the United States, together with a few stations in Lower California, British Columbia, and Alaska Territory, for the year 1886.	75, 12mo.	Do.
1886	Tide tables for the Atlantic coast of the United States for the year 1887.	241, 12mo.	Do.
1886	Tide tables for the Pacific coast of the United States, together with a few stations in Lower California, British Columbia, and Alaska Territory, for the year 1887.	75, 12mo.	Do.
1887	Tide tables for the Atlantic coast of the United States for the year 1888.	242, 12mo.	Do.

List of tide tables from the date of earliest publication, etc.—Continued.

U. S. COAST AND GEODETIC SURVEY—Continued.

Year of publication.	Description.	Number of pages and size.	Mode of publication.
1887	Tide tables for the Pacific coast of the United States, together with a few stations in Lower California, British Columbia, and Alaska Territory, for the year 1888.	80, 12mo.	Pamphlet [Government Printing Office.]
1888	Tide tables for the Atlantic coast of the United States for the year 1889.	242, 12mo.	Do.
1888	Tide tables for the Pacific coast of the United States, together with a few stations in Lower California, British Columbia, and Alaska Territory, for the year 1889.	79, 12mo.	Do.
1889	Tide tables for the Atlantic coast of the United States, together with 206 stations on the Atlantic coast of British America, for the year 1890.	237, large octavo.	Do.
1889	Tide tables for the Pacific coast of the United States, together with 121 stations in Lower California, British Columbia, and Alaska Territory, for the year 1890.	105, large octavo.	Do.
1890	Tide tables for the Atlantic coast of the United States, together with 206 stations on the Atlantic coast of British America, for the year 1891.	250, large octavo.	Do.
1890	Tide tables for the Pacific coast of the United States, together with 121 stations in Lower California, British Columbia, and Alaska Territory, for the year 1891.	111, large octavo.	Do.

V.

CATALOGUE OF COAST PILOTS FOR THE ATLANTIC AND PACIFIC COASTS OF THE UNITED STATES FROM THE DATE OF EARLIEST PUBLICATION BY THE COAST SURVEY TO THE YEAR 1890.

U. S. COAST AND GEODETIC SURVEY.

Year of publication.	Title.	Number of pages and size.	Number of charts, views, etc.	Mode of publication.
1850	Sailing directions to accompany the new chart of the western coast of the United States. (First edition.) Published December, 1850. By A. D. Bache, Superintendent.	13, octavo.	....	Gideon & Co., Printers, Washington, D. C.
1851	Notices of the western coast of the United States. U. S. Coast Survey. A. D. Bache, Superintendent. (Revised edition.) December, 1851.	55, octavo.	....	Do.
1856	Extracts from a report made to the Superintendent by Assistant George Davidson, upon localities on the western coast of the United States from the north entrance of Rosario Strait, Washington Territory, to the southern boundary of California.	10, quarto.	....	Report for 1855—Appendix 26.
1856	Extracts from letters addressed to the Superintendent by Lieut. W. P. Trowbridge, U. S. Engineers, Assistant, relative to Bodega Bay and South Farallon Island, California.	2, quarto.	....	Report for 1855—Appendix 27.
1856	Extracts from the report of Sub-assistant W. M. Johnson relative to the features of Santa Cruz Island, the valley of San Buenaventura, and the coast of Santa Barbara Channel.	3, quarto.	....	Report for 1855—Appendix 28.
1856	Letter of Commander James Alden, U. S. Navy, Assistant, relative to the coast, harbors, and commerce of Washington Territory.	4, quarto.	....	Report for 1855—Appendix 29.
1856	Catalogue of sailing directions, list of dangers, etc., prepared for publication under the direction of the Superintendent.	8, quarto.	....	Report for 1855—Appendix 30.
1856	Report upon the sailing directions for the port of New York and its approaches, taken from the general chart of the Coast Survey, published in 1852, by A. D. Bache, Superintendent U. S. Coast Survey, together with a copy of the sailing directions themselves.	31, octavo.	....	Cambridge. Printed by Allen & Farnham, 1856, for gratuitous distribution by the Life Saving Benevolent Association of New York.
1859	Directory for the Pacific Coast of the United States, reported to the Superintendent of the United States Coast Survey by George Davidson, Assistant. (First edition.)	162, quarto.	....	Coast Survey report, 1858—Appendix 44.
1864	The same. (Second edition.)	163, quarto.	....	Coast Survey report, 1862—Appendix 39.
1869	Report of Assistant George Davidson relative to the resources and the coast features of Alaska Territory. NOTE.—This report, which is the basis of the Coast Pilot of Alaska, published in the same year as a separate volume, was first submitted for publication by Mr. Davidson on November 30, 1867.	143, quarto.	4	Coast Survey report, 1867—Appendix 18.

Catalogue of Coast Pilots for the Atlantic and Pacific Coasts, etc.—Continued.

U. S. COAST AND GEODETIC SURVEY—Continued.

Year of publication.	Title.	Number of pages and size.	Number of charts, views, etc.	Mode of publication.
1869	Pacific Coast. Coast Pilot of California, Oregon, and Washington Territory. By George Davidson, Assistant, Coast Survey.	262, quarto.	33	1 vol., Government Printing Office, 1869.
1869	Pacific Coast. Coast Pilot of Alaska. (First part.) From southern boundary to Cook's Inlet. By George Davidson, Assistant, Coast Survey.	251, quarto.	8	1 vol., Government Printing Office, 1869.
1875	Coast Pilot for the Atlantic sea-board. Gulf of Maine and its coast from Eastport to Boston. 1874. By J. S. Bradford, Assistant.	960, quarto.	12	1 vol., Government Printing Office, 1875.
1878	Atlantic Coast Pilot. Boston Bay to New York.	628, quarto.	55	1 vol., Government Printing Office, 1878.
1879	Atlantic Coast Pilot. Boston Bay to Monomoy.	92, quarto.	4	1 vol., Government Printing Office, 1879.
1879	Atlantic Coast Pilot. Nantucket and Vineyard Sounds.	107, quarto.	7	1 vol., Government Printing Office, 1879.
1879	Atlantic Coast Pilot. Buzzard's and Narragansett Bays.	122, quarto.	4	1 vol., Government Printing Office, 1879.
1879	Atlantic Coast Pilot. Block Island and Fisher's Island Sounds, Gardiner's and Peconic Bays.	66, quarto.	4	1 vol., Government Printing Office, 1879.
1879	Atlantic Coast Pilot. Long Island Sound and East River.	86, quarto.	6	1 vol., Government Printing Office, 1879.
1879	Atlantic Coast Pilot. Harbors in Long Island Sound.	112, quarto.	4	1 vol., Government Printing Office, 1879.
1879	Atlantic Coast Pilot. South coast of Long Island, New York Bay, and Hudson River.	90, quarto.	22	1 vol., Government Printing Office, 1879.
	NOTE.—The seven volumes above named, published early in the year 1879, comprise a series intended to meet local wants, and are all contained in the one volume of the Atlantic Coast Pilot for 1878, compiled and verified by J. S. Bradford, Assistant.			
1879	Atlantic Coast Pilot. Division A. Eastport to Boston. (Second edition.)	694, quarto.	56	1 vol., Government Printing Office, 1879.
1879	Atlantic Local Coast Pilot. Subdivision 1. Passamaquoddy Bay to Schoodic.	115, quarto.	10	1 vol., Government Printing Office, 1879.
1879	Atlantic Local Coast Pilot. Subdivision 2. Frenchmans Bay to Isle-au-haut.	196, quarto.	7	1 vol., Government Printing Office, 1879.
1879	Atlantic Local Coast Pilot. Subdivision 3. Penobscot Bay and tributaries. (First edition.)	121, quarto.	18	1 vol., Government Printing Office, 1879.
1879	Atlantic Local Coast Pilot. Subdivision 4. White Head Island to Cape Small Point.	126, quarto.	6	1 vol., Government Printing Office, 1879.
1879	Atlantic Local Coast Pilot. Subdivision 5. Cape Small Point to Cape Ann.	141, quarto.	10	1 vol., Government Printing Office, 1879.
1879	Atlantic Local Coast Pilot. Subdivision 6. Cape Ann to Cohasset.	107, quarto.	5	1 vol., Government Printing Office, 1879.
	NOTE.—The six volumes of the Atlantic Local Coast Pilot named above and published about the middle of the year 1879, appear as separate parts of the large volume "Atlantic Coast Pilot, Division A, Eastport to Boston" (second edition), compiled by J. S. Bradford, Assistant.			

Catalogue of Coast Pilots for the Atlantic and Pacific Coasts, etc.—Continued.

U. S. COAST AND GEODETIC SURVEY—Continued.

Year of publication.	Title.	Number of pages and size.	Number of charts, views, etc.	Mode of publication.
1879	Pacific Coast Pilot. Coast and islands of Alaska. Second series. Appendix I. Meteorology and Bibliography. By W. H. Dall, Assistant.	375, quarto.	27	1 vol., Government Printing Office, 1879.
1880	Atlantic Coast Pilot. Division B. Boston to New York. (Second edition.)	675, quarto.	53	1 vol., Government Printing Office, 1880.
1880	Atlantic Local Coast Pilot. Subdivision 7. Boston to Monomoy. (Second edition.)	86, quarto.	5	1 vol., Government Printing Office, 1880.
1880	Atlantic Local Coast Pilot. Subdivision 8. Nantucket and Vineyard Sounds. (Second edition.)	116, quarto.	9	1 vol., Government Printing Office, 1880.
1880	Atlantic Local Coast Pilot. Subdivision 9. Buzzard's and Narragansett Bays. (Second edition.)	131, quarto.	5	1 vol., Government Printing Office, 1880.
1880	Atlantic Local Coast Pilot. Subdivision 10. Block Island and Fisher's Island Sounds; Gardiner's and Peconic Bays. (Second edition.)	70, quarto.	5	1 vol., Government Printing Office, 1880.
1880	Atlantic Local Coast Pilot. Subdivision 11. Long Island Sound and East River. (Second edition.)	92, quarto.	6	1 vol., Government Printing Office, 1880.
1880	Atlantic Local Coast Pilot. Subdivision 12. Harbors in Long Island Sound. (Second edition.)	126, quarto.	4	1 vol., Government Printing Office, 1880.
1880	Atlantic Local Coast Pilot. Subdivision 13. South coast of Long Island, New York Bay, and Hudson River. (Second edition.)	95, quarto.	21	1 vol., Government Printing Office, 1880.
	NOTE.—The volumes of the Atlantic Local Coast Pilot numbered as Subdivisions 7 to 13 inclusive, and enumerated as above, appear as separate parts of the large volume Atlantic Coast Pilot, Division B, Boston to New York (second edition), and like that volume were compiled and prepared for publication by J. S. Bradford, Assistant.			
1882	Atlantic Local Coast Pilot. Subdivision 14. New York to Delaware entrance. (First edition.)	95, quarto.	13	1 vol., Government Printing Office, 1882.
1883	Atlantic Local Coast Pilot. Subdivision 15. Delaware Bay and tributaries. (First edition.)	159, quarto.	11	1 vol., Government Printing Office, 1883.
1883	Pacific Coast Pilot. Alaska. Part I. Coast from Dixon entrance to Yakutat Bay, with the inland passage.	342, quarto.	53	1 vol., Government Printing Office, 1883.
1885	Atlantic Local Coast Pilot. Subdivision 19. Cape Henry to Winyah Bay, and inside passages. (First edition.)	89, quarto.	21	1 vol., Government Printing Office, 1885.
1885	Atlantic Local Coast Pilot. Subdivision 20. Winyah Bay to Savannah, with the inland passage to Fernandina. (First edition.)	86, quarto.	17	1 vol., Government Printing Office, 1885.
1886	Atlantic Local Coast Pilot. Subdivision 13. South coast of Long Island, New York Bay, and Hudson River. (Third edition.)	99, quarto.	8	1 vol., Government Printing Office, 1886.
1887	Atlantic Local Coast Pilot. Subdivision 21. Tybee Roads to Jupiter Inlet. (First edition.)	106, quarto.	11	1 vol., Government Printing Office, 1887.
1888	Atlantic Local Coast Pilot. Subdivisions 6–7. Cape Ann to Monomoy. (Third edition.)	143, quarto.	9	1 vol., Government Printing Office, 1888.

Catalogue of Coast Pilots for the Atlantic and Pacific Coasts, etc.—Continued.

U. S. COAST AND GEODETIC SURVEY—Continued.

Year of publication.	Title.	Number of pages and size.	Number of charts, views, etc.	Mode of publication.
1888	United States Coast Pilot. Atlantic Coast. Part IV.* Long Island Sound, with approaches and adjacent waters. (First edition.)	155, quarto.	15	1 vol., Government Printing Office, 1888.
1889	United States Coast Pilot. Atlantic Coast. Part VI. Chesapeake Bay and tributaries. (First edition.)	135, quarto.	33	1 vol., Government Printing Office, 1889.
1889	Atlantic Local Coast Pilot. Subdivision 22. Straits of Florida, Jupiter Inlet to Dry Tortugas. (First edition.)	95, quarto.	2	1 vol., Government Printing Office, 1889.
1889	Pacific Coast. Coast Pilot of California, Oregon, and Washington, By George Davidson, Assistant. (Fourth edition.)	721, quarto.	457	1 vol., Government Printing Office, 1889.
	NOTE.—At the date at which this Catalogue goes to press there has been published another volume of the series designated as the "United States Coast Pilot," which is to appear first in Parts, and later in a large volume intended to embrace the Atlantic coast of the United States. The title of this volume is "United States Coast Pilot. Atlantic Coast. Parts I and II. From the St. Croix River to Cape Ann. (First edition.)"			

* This volume takes the place of Subdivisions 10, 11, and 12, Atlantic Local Coast Pilot, and of pp. 304-549 of Division B, Atlantic Coast Pilot.

VI.

CATALOGUES OF MAPS AND CHARTS PUBLISHED BY THE U. S. COAST AND GEODETIC SURVEY BETWEEN THE YEARS 1843 AND 1890.

U. S. COAST AND GEODETIC SURVEY.

Date of publication. Catalogue.	Date of publication. Charts.	Title of catalogue.	Number of pages and size.	No. of maps and charts.	Mode of publication.
1843	1835–1842	List of the individual maps executed and delivered. NOTE.—The list above named is published also in Report No. 170, designated as Twenty-seventh Congress, third session, Report No. 170, House of Representatives.	1, octavo.	8	Twenty-seventh Congress, third session. House Report No. 43. (Report of Select Committee on Coast Survey.)
1849	1842–1849	List of Coast Survey maps engraved.	1, octavo.	33	Thirty-first Congress, first session. Senate Ex. Doc. No. 5. (Report of Superintendent Coast Survey for 1849. Appendix No. 2, *bis.*)
1850	1842–1850	......do	1, octavo.	43	Thirty-first Congress, second session. House Ex. Doc. No. 12. (Report of Superintendent Coast Survey for 1850. Appendix No. 38.)
1852	1842–1851	List of Coast Survey maps, sketches, and preliminary charts, engraved.	2, octavo.	78	Thirty-second Congress, first session. Senate Ex. Doc. No. 3. (Report of Superintendent Coast Survey for 1851. Appendix No. 11.)
1853	1842–1852	List of Coast Survey maps, sketches, and preliminary charts.	2, quarto.	89	Thirty-second Congress, second session. Executive No. 64, House of Representatives. (Report of Superintendent Coast Survey for 1852. Appendix 6.)
1854	1842–1853	List of Coast Survey maps, sketches, and preliminary charts.	2, quarto.	129	Thirty-third Congress, first session, Executive 14, Senate. (Report of Superintendent Coast Survey for 1853. Appendix 5.)
1855	1842–1854	......do	3, quarto.	147	Thirty-third Congress, second session, Executive 20, House of Representatives. (Report of Superintendent Coast Survey for 1854. Appendix 31.)
1856	1842–1855	......do	4, quarto.	192	Thirty-fourth Congress, first session, Executive 6, House of Representatives. (Report of Superintendent Coast Survey for 1855. Appendix 36.)
1856	1842–1856	List of Coast Survey maps, preliminary charts, and sketches, engraved, geographically arranged.	5, quarto.	221	Thirty-fourth Congress, third session, Executive 12, Senate. (Report of Superintendent Coast Survey for 1856. Appendix 19.)

Catalogues of Maps and Charts, etc.—Continued.

U. S. COAST AND GEODETIC SURVEY—Continued.

Date of publication.		Title of catalogue.	Number of pages and size.	No. of maps and charts.	Mode of publication.
Catalogue.	Charts.				
1858	1842-1857	List of Coast Survey maps, preliminary charts, and sketches, engraved, geographically arranged.	6, quarto.	240	Thirty-fifth Congress, first session, Executive 33, Senate. (Report of Superintendent Coast Survey for 1857. Appendix 22.)
1859	1842-1858	......do	6, quarto.	260	Thirty-fifth Congress, second session, Executive 14, Senate. (Report of Superintendent Coast Survey for 1858. Appendix 19.)
1860	1842-1859	......do	6, quarto.	268	Thirty-sixth Congress, first session, Executive 41, House of Representatives. (Report of Superintendent Coast Survey for 1859. Appendix 17.)
1861	1842-1860	......do	6, quarto.	278	Thirty-sixth Congress, second session, Executive —, Senate. (Report of Superintendent Coast Survey for 1860. Appendix 19.)
1862	1842-1861	......do	6, quarto.	290	Thirty-seventh Congress, second session, Executive —, Senate. (Report of Superintendent Coast Survey for 1861. Appendix 12.)
1863	1846-1863	Catalogue of hydrographic maps, charts, and sketches published by the U. S. Coast Survey.—A. D. Bache, Superintendent, 1863.	17, quarto.	242	Washington. Government Printing Office. 1863.
1866	1846-1864	Catalogue of hydrographic maps, charts, and sketches published by the U. S. Coast Survey.—A. D. Bache, Superintendent. 1866.	17, quarto.	242	Washington. Government Printing Office.
1867	1846-1867	Same.—Benjamin Peirce, Superintendent. 1867.	18, quarto.	276	Do.
1872	1846-1872	Same.—Benjamin Peirce, Superintendent. 1872.	20, quarto.	278	Do.
1875	1851-1875	U. S. Coast Survey.—Carlile P. Patterson. Superintendent. Catalogue of charts. 1875.	28, quarto.	299	Do.
1877	1851-1877	Catalogue of charts of the U. S. Coast Survey, 1877.—Carlile P. Patterson, Superintendent.	29, quarto.	325	Do.
1880	1846-1880	U. S. Coast and Geodetic Survey. Catalogue of charts, 1880.—Carlile P. Patterson, Superintendent.	45, quarto.	409	Washington. Government Printing Office.
1883	1846-1883	U. S. Coast and Geodetic Survey. Catalogue of charts, 1883.—J. E. Hilgard, Superintendent.	64, quarto.	389	Do.
1884	1846-1884	U. S. Coast and Geodetic Survey. Catalogue of charts, 1884.—J. E. Hilgard, Superintendent.	68, quarto.	384	Do.
1886	1846-1886	U. S. Coast and Geodetic Survey. Catalogue of charts, 1886.—F. M. Thorn, Superintendent.	72, quarto.	395	Do.

Catalogues of Maps and Charts, etc.—Continued.

U. S. COAST AND GEODETIC SURVEY—Continued.

Date of publication.		Title of catalogue.	Number of pages and size.	No. of maps and charts.	Mode of publication.
Catalogue.	Charts.				
1887	1846–1887	U. S. Coast and Geodetic Survey. Catalogue of charts and other publications, 1887.—F. M. Thorn, Superintendent.	140, quarto.	458	Washington. Government Printing Office.
1890	1846–1890	U. S. Coast and Geodetic Survey. Catalogue of charts and other publications, 1890.—T. C. Mendenhall, Superintendent.	156, quarto.	476	Do.

NOTE.—A catalogue of charts for 1892 is in press at the date of compilation of this appendix.

VII.

NOTICES TO MARINERS FROM THE DATE OF EARLIEST PUBLICATION BY THE COAST SURVEY TO THE YEAR 1890.

This list begins with the earliest separate publication of these notices on file in the Coast and Geodetic Survey Office. The annual reports previous to 1869 contain many such notices in the form of communications from the Superintendent to the Secretary of the Treasury, with requests that authority be given to publish for the benefit of mariners. The separate publications of these notices since 1869 are for special distribution, and are supplementary to the publication formerly made and still continued in the leading commercial and nautical journals. For general lists of discoveries and developments see the Reports from 1850 to 1864, inclusive.

U. S. COAST AND GEODETIC SURVEY.

Number.	Date of notice.	Title.
	1869, July 12	Notice to Mariners. Pacific Coast. Shoal off Cape Reyes, California.
	1872, Jan. 22	Notice to Mariners. Atlantic Coast. East coast of Florida. St. Lucie Shoal.
	1874, June 20	Notice to Mariners. Northwest coast of America. Aleutian Islands.
	1874, Oct. 10	Notice to Mariners. Atlantic Coast. Long Island Sound.
1	1875, Jan. 14	Notice to Mariners, No. 1. Atlantic Coast. Sailing directions for St. Augustine Harbor.
2	1875, Jan. 26	Notice to Mariners, No. 2. Pacific Coast. Sailing directions for Macks Shelter, Oregon.
3	1875, Feb. 10	Notice to Mariners, No. 3. Pacific Coast. Sunken rock off the boundary of California and Oregon.
4	1875, May 4	Notice to Mariners, No. 4. Pacific Coast. Additional peaks, Noonday Rock, entrance to San Francisco Bay, California.
5	1875, May 7	Notice to Mariners, No. 5. Pacific Coast. Sunken rock off Cape Mendocino, California.
6	1875, May 20	Notice to Mariners, No. 6. Pacific Coast. Sunken Rocks. San Luis Obispo Bay, California.
7	1875, July 24	Notice to Mariners, No. 7. Pacific Coast. Shoal near South Farallon.
8	1875, Sept. 4	Notice to Mariners, No. 8. Pacific Coast. Dangerous shoal in the northern approach to San Miguel Passage.
9	1875, Sept. 20	Notice to Mariners, No. 9. Atlantic Coast. Approaches to Chesapeake Bay. Wreck 12 miles to the southward and eastward of Cape Henry.
10	1875, Nov. 4	Notice to Mariners, No. 10. Atlantic Coast. Ledge in Delaware River.
11	1876, Feb. 8	Notice to Mariners, No. 11. Gulf of Mexico. Positions of wrecks at the entrance of Pensacola Bay, Florida.
12	1877, May 16	Notice to Mariners. No. 12. Atlantic Coast. Chesapeake Bay. Wreck off New Point Comfort, Virginia.
13	1877, Dec. 15	Notice to Mariners, No. 13. Atlantic Coast. Wreck off Currituck Beach, North Carolina.
14	1877, Dec. 21	Notice to Mariners, No. 14. Gulf of Mexico. Observations upon northers and southeast gales.
15	1878, Mar. 7	Notice to Mariners, No. 15. Gulf of Maine. Tidal currents at entrance.
15	1878, June 15	Notice to Mariners, No. 15. Gulf of Maine. Tidal currents at entrance. [Second edition.]
16	1878, May 9	Notice to Mariners, No. 16. Atlantic Coast. Florida Reefs. Disappearance of a beacon.
17	1878, July 16	Notice to Mariners, No. 17. Atlantic Coast. Nantucket Sound. Wreck in Hyannis Harbor.
18	1879, June 27	Notice to Mariners, No. 18. Pacific Coast. Depth of water over the bar at entrance of Wilmington Harbor, California.
19	1879, June 27	Notice to Mariners, No. 19. Coast of Alaska. Location of Keen Rock in the middle passage to Sitka Harbor, Alaska.

Notices to mariners from the date of earliest publication, etc.—Continued.

U. S. COAST AND GEODETIC SURVEY.

Number.	Date of notice.	Title.
20	1879, June 27	Notice to Mariners, No. 20. Atlantic Coast. Closing of New Inlet, mouth of Cape Fear River, North Carolina.
21	1879, July 9	Notice to Mariners, No. 21. Atlantic Coast. Increased depth of water at entrance of Cape Fear River, North Carolina.
22	1879, July 14	Notice to Mariners, No. 22. Atlantic Coast. Sunken wreck in the track of vessels running along the New Jersey coast.
23	1879, July 25	Notice to Mariners, No. 23. Atlantic Coast. Development of Johnsons Rock, Casco Bay, Maine.
24	1879, Oct. 14	Notice to Mariners, No. 24. Atlantic Coast. Dangerous rock near Isle of Wight Shoal, coast of Maryland.
25	1879, Nov. 15	Notice to Mariners, No. 25. Atlantic Coast. Development of Schuylers Ledge, off Sakonnet Point, Rhode Island.
26	1880, June 7	Notice to Mariners, No. 26. Pacific Coast. Development of dangerous rocks near Fort Ross, California.
27	1880, Dec. 16	Notice to Mariners, No. 27. Atlantic Coast. Sunken wreck in entrance to Rappahannock River, Virginia.
28	1881, Apr. 26	Notice to Mariners, No. 28. Atlantic Coast. Improvements of rivers and harbors on the coasts of Maine and Massachusetts, under the direction of Gen. George Thom, Engineer Corps, U. S. Army.
29	1881, Apr. 27	Notice to Mariners, No. 29. Atlantic Coast. Connecticut. Breakwater in process of construction to the westward of Bartletts Reef, Fishers Island Sound.
30	1881, June 1	Notice to Mariners, No. 30. Atlantic Coast. Sunken wreck off the east coast of Florida.
31	1881, June 1	Notice to Mariners, No. 31. Pacific Coast. Reported dangers in the approaches to St. Paul Harbor, Kadiak Island, Alaska.
32	1881, July 20	Notice to Mariners, No. 32. Atlantic Coast. New shoal. Frying-Pan Shoals, off Cape Fear, North Carolina.
33	1881, Nov. 10	Notice to Mariners, No. 33. Atlantic Coast. Development of Fiske Rock, Narragansett Bay, Rhode Island.
34	1882, Aug. 24	Notice to Mariners, No. 34. Atlantic Coast. Dangerous rock in eastern entrance to Fishers Island Sound.
		NOTE.—The greater number of the above-named notices are printed somewhat as handbills, in large type for easy reading, and occupy about one page quarto.
35	1883, Jan. 14	Notice to Mariners, No. 35. Atlantic Coast. Dangerous rocks in western part of Fishers Island Sound. Approaches to New London and Mystic Harbors.
36	1883, May 14	Notice to Mariners, No. 36. Atlantic Coast. Sunken wreck in the track of vessels along the New Jersey coast.
37	1883, June 8	Notice to Mariners, No. 37. Atlantic Coast. Wreck in the track of vessels along the east coast of Florida.
38	1883, June 19	Notice to Mariners, No. 38. Pacific Coast. Discovery of a rock in Surge (or Southern) Narrows, Peril Strait, southeast Alaska.
39	1883, June 22	Notice to Mariners, No. 39. Atlantic Coast. Wreck in the track of coasting vessels off New Jersey.
40	1883, Oct. 31	Notice to Mariners, No. 40. Atlantic Coast. Dangerous rock off Warrens Point, Rhode Island.
41	1883, Nov. 9	Notice to Mariners, No. 41. Atlantic Coast Dangerous rocks recently reported on the coast of Maine, near Muscongus and Booth Bays. Wreck off Tarpaulin Cove, Vineyard Sound.
42	1883, Nov. 13	Notice to Mariners, No. 42. Atlantic Coast. Rock reported in Eggemoggin Reach, Maine. Rocks in East River, New York, near North Brother and Rikers Islands.
43	1883, Nov. 26	Notice to Mariners, No. 43. Atlantic Coast. Dangerous shoals off Cape Henlopen, Delaware.
44	1883, Dec. 8	Notice to Mariners, No. 44. Atlantic Coast. Wreck in Potomac River, near Blackistone Island.
45	1884, Mar. 20	Notice to Mariners, No. 45. Atlantic Coast. Dangerous shoals in Monomoy Passage.
46	1884, May 27	Notice to Mariners, No. 46. Pacific Coast. Notes on dangers in Neva and Peril Straits and anchorages in Fish Bay, Southeast Alaska.
47	1884, May 28	Notice to Mariners, No. 47. Atlantic Coast. Dangerous ledges in Fishers Island Sound.

Notices to Mariners from the date of the earliest publication, etc.—Continued.

U. S. COAST AND GEODETIC SURVEY—Continued.

Number.	Date of notice.	Title.
48	1884, May 31	Notice to Mariners, No. 48. Atlantic Coast. Dangerous rock in East River, New York.
49	1884, June 1	Notice to Mariners, No. 49. Atlantic Coast. Dangerous ledge in Englishmans Bay, coast of Maine.
50	1884, June 10	Notice to Mariners, No. 50. Atlantic Coast. Development of ledges off Minots Ledge Lighthouse, Massachusetts Bay.
51	1884, June 30	Notice to Mariners, No. 51. Atlantic Coast. Important changes at and near Cape Henlopen.
52	1884, Aug. 11	Notice to Mariners, No. 52. Atlantic Coast. Dangerous rock in East River, New York.
53	1884, Sept. 15	Notice to Mariners, No. 53. Changes in the pilotage laws of the port of New York.
54	1884, Oct. 7	Notice to Mariners, No. 54. Atlantic Coast. Rocks recently reported on the coast of New England.
55	1884, Nov. 1	Notice to Mariners, No. 55. Atlantic Coast. I. Dangerous ledges developed in the resurvey of Long Island Sound. II. Ledge near Seal Rock, Rhode Island.
56	1884, Nov. 15	Notice to Mariners, No. 56. Atlantic Coast. Shoal developed in Vineyard Sound.
57	1884, Nov. 15	Notice to Mariners, No. 57. Pacific Coast. Discovery of a rock in Security Bay, Kuin Island, Chatham Strait, Alaska.
58	1885, Feb. 10	Notice to Mariners, No. 58. Atlantic Coast. I. Development of shoals in Narragansett Bay, Rhode Island, and Block Island Sound. II. Development of Sabine Bank, off Sabine Pass, Gulf of Mexico.
59	1885, Mar. 23	Notice to Mariners, No. 59. Atlantic Coast. Changes in main ship-channel, Vineyard Sound.
60	1885, Mar. 23	Notice to Mariners, No. 60. Pacific Coast. Sailing directions for Wrangell Strait, Alaska.
61	1885, June 12	Notice to Mariners, No. 61. Pacific Coast. Sailing directions for inland passage between Sitka Harbor and Hooniah Sound, through Olga Strait, Neva Strait, and Peril Straits, Alaska.
62	1885, July 1	Notice to Mariners, No. 62. Gulf of Mexico. Shoal developed near Marquesas Keys, Florida.
63	1885, Aug. 24	Notice to Mariners, No. 63. Atlantic Coast. Ledges developed in the resurvey of Long Island Sound.
64	1885, Oct. 6	Notice to Mariners, No. 64. Atlantic Coast. Dangerous rock developed in the resurvey of East River, New York.
65	1885, Oct. 12	Notice to Mariners, No. 65. Atlantic Coast. Dangers developed in the resurvey of East River, New York.
66	1885, Oct. 21	Notice to Mariners, No. 66. Atlantic Coast. Development of bar between Thatchers Island and Milk Island, Massachusetts.
67	1885, Oct. 21	Notice to Mariners, No. 67. Atlantic Coast. Ledge developed in Boston Bay, Massachusetts.
68	1885, Nov. 20	Notice to Mariners, No. 68. Atlantic Coast. Dangers developed in the resurvey of East River, New York.
69	1885, Nov. 20	Notice to Mariners, No. 69. Atlantic Coast. Important changes in Monomoy Passage, Massachusetts.
70	1885, Nov. 20	Notice to Mariners, No. 70. Atlantic Coast. Ledge developed in Fishers Island Sound, Connecticut.
71	1885, Dec. 7	Notice to Mariners, No. 71. Atlantic Coast. Examination of dangers reported on the coast of Maine.
72	1886, Mar. 31	Notice to Mariners, No. 72.* Coast of the United States. Chart corrections during the quarter ending March 31, 1886.
73	1886, May 12	Notice to Mariners, No. 73. Dangerous wreck on Charleston Bar.
74	1886, May 21	Notice to Mariners, No. 74. Atlantic Coast. Dangerous wreck on Charleston Bar. (Addition to Notice to Mariners, No. 73.)
75	1886, May 31	Notice to Mariners, No. 75. Atlantic Coast. Danger developed in the resurvey of East River, New York.
76	1886, June 30	Notice to Mariners, No. 76. Coast of the United States. Chart corrections during the quarter ending June 30, 1886.
77	1886, Sept. 30	Notice to Mariners, No. 77. Coast of the United States. Chart corrections during the quarter ending September 30, 1886.

* NOTE.—This was the first number of the quarterly series of these notices, the publication of which was recommended by the Hydrographic Inspector.

Notices to Mariners from the date of the earliest publication, etc.—Continued.

U. S. COAST AND GEODETIC SURVEY—Continued.

Number.	Date of notice.	Title.
78	1886, Oct. 13	Notice to Mariners, No. 78. Atlantic Coast. Velocity and direction of the Gulf Stream between Fowey Rocks, Florida, and Gun Cay, Bahamas.
79	1886, Oct. 15	Notice to Mariners, No. 79. Atlantic Coast. Development of shoals off False Cape, Virginia.
80	1886, Oct. 23	Notice to Mariners, No. 80. Atlantic Coast. Ledges developed in the resurvey of Long Island Sound.
81	1886, Nov. 8	Notice to Mariners, No. 81. Coast of the United States. Correction of an error in Notice to Mariners, No. 77.
82	1886, Dec. 1	Notice to Mariners, No. 82. Atlantic Coast. Ledge developed in East River, New York.
83	1886, Dec. 31	Notice to Mariners, No. 83. Coast of the United States. Chart corrections during the quarter ending December 31, 1886.
84	1887, Jan. 8	Notice to Mariners, No. 84. Atlantic Coast. Obstruction to navigation in the Gulf Stream.
85	1887, Mar. 31	Notice to Mariners, No. 85. Coast of the United States. Chart corrections during the quarter ending March 31, 1887.
86	1887, Apr. 16	Notice to Mariners, No. 86. Atlantic Coast. Dangerous sunken wreck in Long Island Sound.
87	1887, June 9	Notice to Mariners, No. 87. Atlantic Coast. Shoal spot on rocky ledge off Eatons Point, Long Island Sound, New York.
88	1887, June 30	Notice to Mariners, No. 88. Coast of the United States. Chart corrections during the quarter ending June 30, 1887.
89	1887, July 30	Notice to Mariners, No. 89. Coast of the United States. Chart corrections during the month of July, 1887.
		NOTE.—With this number was begun the monthly series of these notices, as follows:
89-92	1887	Nos. 89 to 92, inclusive. Chart corrections for the months of July, August, September, and October, 1887.
93	1887, Nov. 8	Notice to Mariners (1887), No. 93. Atlantic Coast. Dangerous rock in Vineyard Sound, Massachusetts.
94	1887, Nov. 22	Notice to Mariners (1887), No. 94. Coast of the United States. Gulf Stream currents.
95-96	1887	Nos. 95 and 96. Chart corrections for the months of November and December, 1887.
	....	Index to U. S. Coast and Geodetic Survey Notices to Mariners (Nos. 1 to 96).
97	1888, Jan. 9	Notice to Mariners, No. 97. Coast of the United States. Coast currents approaching Sandy Hook.
98-109	1888	Nos. 98 to 109, inclusive. Chart corrections for the months of January, February, March, April, May, June, July, August, September, October, November, and December, 1888.
	....	Index to U. S. Coast and Geodetic Survey Notices to Mariners published during 1888 (Nos. 97 to 109).
	....	U. S. Coast and Geodetic Survey. Index to chart corrections. January 1 to December 31, 1888.
110-113	1889	Nos. 110 to 113, inclusive. Chart corrections for the months of January, February, March, and April, 1889.
114	1889, May 1	Notice to Mariners (1889), No. 114. Atlantic Coast. Off-shore current observations. Information of special importance to mariners.
115-117	1889	Nos. 115 to 117, inclusive. Chart corrections for the months of May, June, and July, 1889.
118	1889, Aug. 15	Notice to Mariners (1889), No. 118. Information concerning U. S. Coast and Geodetic Survey charts.
119-123	1889	Nos. 119 to 123, inclusive. Chart corrections for the months of August, September, October, November, and December, 1889.
	....	U. S. Coast and Geodetic Survey. Index to chart corrections, 1889. January 1 to December 31.
124-135	1890	Nos. 124 to 135, inclusive. Chart corrections for the months of January, February, March, April, May, June, July, August, September, October, November, and December, 1890.
136	1890, Dec. 31	U. S. Coast and Geodetic Survey. Index to chart corrections. January 1 to December 31, 1890. (Notice to Mariners, No. 136.)

VIII.

BULLETINS.

Bulletins are issued by the Survey from time to time as material for them accumulates. They are intended to give early announcement of work accomplished or information of importance obtained, and will in many cases anticipate the usual means of publication afforded by the Annual Reports. The pages are numbered consecutively, and will be indexed when their number demands it, thus augmenting their value for preservation and reference.

No.	Date of publication.	Title.	Pages.
1	1888, May 14	Recent Publications	1
2	1888, June 20	Notes on Alaska from Recent Surveys	3–6
3	1888, Aug. —	Tidal Levels and Flow of Currents in New York Bay and Harbor. (Two illustrations.) By Henry L. Marindin, Assistant.	7–12
4	1888, May 25	Resources of and Developments in Alaska. By George Davidson, Assistant.	13–24
5	1888, May 1	The value of the "Arcano del Mare" with reference to our knowledge of the Magnetic Declination in the earlier part of the Seventeenth Century. By Charles A. Schott, Assistant. (Two illustrations.)	25–28
6	1888, May 5	Secular Variation in the Position of the Agonic line of the North Atlantic and of America, between the epochs 1500 and 1900 A. D. By Charles A. Schott, Assistant. (Three illustrations.)	29–43
7	1888, June 7	Historical Review of the work of the Coast and Geodetic Survey in connection with terrestrial magnetism. By Charles A. Schott, Assistant. (Four plates.)	35–40
8	1889, Feb. 18	Currents of New York Bay and Harbor. Compiled by B. A. Colonna, Assistant, from the notes of a physical survey by H. L. Marindin, Assistant. (Second edition.)	41–43
		NOTE.—This supersedes the first edition, the issue of which was suppressed.	
9	1889, June 15	On the Relation of the Yard to the Metre. By O. H. Tittmann, Assistant.	45–50
10	1889, Jan. 30	Report on the Sounds and Estuaries of North Carolina with reference to Oyster Culture. By Francis Winslow, Lieutenant, U. S. N., Assistant, U. S. Coast and Geodetic Survey, Commanding schooner Scoresby. (Three illustrations.)	51–136
11	1889, Apr. 23	Determinations of Latitude and Gravity for the Hawaiian Government. By E. D. Preston, Assistant. (One plate and three progress maps.)	137–142
12	1889, Mar. 30	A Syphon Tide-Gauge for the open Seacoast. By Henry L. Marindin, Assistant. (One plate.)	143–146
13	1889, Oct. 7	Telegraphic Determination of the Longitude of Mount Hamilton, California. Fieldwork by C. H. Sinclair, Assistant, and R. A. Marr, Subassistant. Report by Charles A. Schott, Assistant.	147–150
14	1889, Nov. 21	Approximate Times of Culminations and Elongations and of the Azimuths at Elongation of Polaris for the years between 1889 and 1910. Prepared for publication by Charles A. Schott, Assistant.	151–155
15	1889, Nov. 30	Verification of Weights and Measures. By O. H. Tittmann, Assistant. (One plate.)	157–158
16	1889, Oct. 7	Description of two new transit instruments for longitude work. Constructed at the office of the Survey from designs by Edwin Smith, Assistant. (One plate.)	161–164
17	1889, June 15	The relation between the Metric Standards of Length of the U. S. Coast and Geodetic Survey and the U. S. Lake Survey. A report by C. A. Schott and O. H. Tittmann, Assistants, Coast and Geodetic Survey.	165–173
18	1890, Feb. 18	Table for the Reduction of Hydrometer Observations of Salt-Water Densities. Prepared for publication by O. H. Tittmann, Assistant.	175–177
19	1890, Mar. 15	On the Sounds and Estuaries of Georgia with reference to Oyster Culture. A report by J. C. Drake, Ensign, U. S. N., Assistant, U. S. Coast and Geodetic Survey, Commanding schooner Ready, 1889–1890. (Seven charts.)	179–209

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20	1890, Dec. 12	The Magnetic Observations made on Bering's First Voyage to the Coasts of Kamchatka and Eastern Asia in the years 1725 to 1730. Discussion by C. A. Schott, Assistant.	211-214
21	1890, Dec. 12	Determination of an Azimuth from Micrometric Observations of a Close Circumpolar Star near Elongation, by means of a meridian or transit and equal altitude instrument or by means of a theodolite with eye-piece micrometer. Report on method, and example of computation by Charles A. Schott, Assistant. Observations by A. T. Mosman, Assistant.	215-218

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ALPHABETICAL INDEX—Continued.

APPENDIX No. 12.—1891.

THE TRANSIT OF MERCURY OF MAY 9, 1881, AS OBSERVED AT WAIKIKI, HAWAIIAN ISLANDS.

A report by E. D. PRESTON, Assistant.

Submitted for publication September 8, 1891.

PREFATORY NOTE.

Assistant E. D. Preston, having been detailed for duty in observing the variations of latitude in coöperation with Dr. Marcuse, representing the International Geodetic Association, and having been directed to occupy stations on the Hawaiian Islands, advantage was taken of his expected arrival at Honolulu, Island of Oahu, early in May, 1891, to obtain observations of the transit of Mercury on the 9th of that month.

REPORT.

The observations of the transit of Mercury in the Hawaiian Islands on May 9, 1891, were made possible by the kind coöperation of the Hawaiian Government Survey. When, about April 15, it appeared probable that we would only arrive at Honolulu the day preceding the transit, I immediately wrote to Prof. Alexander, the Surveyor-general, asking that a chronometer might be rated for the occasion. This was done by Mr. C. J. Lyons. The mail steamer *Monowai* arrived in port at 1 p. m. of May 8. Our chronometers were immediately uncorked and started, and then compared with the standard clock in the office of the Hawaiian Survey.

During the afternoon several places were visited in search of a suitable site for the observations. An approximate computation revealed the fact that the last contact would occur only a very few minutes before sundown, so that it was necessary to observe from a spot giving a perfectly clear horizon to the west-northwest. This point was found at Waikiki, a place about 3 miles southeast of Honolulu and about

midway between the two beautiful craters of Diamond Head (Leahi) and the Punch Bowl (Puowaina). The latitude and longitude of the station are:

$$\varphi = 21^\circ\ 16'\ 21''\ \text{North.}$$
$$\lambda = 157^\circ\ 49'\ 40''\ \text{West.}$$

We left Honolulu about 10 a. m. of May 9. Arriving at Waikiki, the instruments were set up and adjusted in the yard of the Johnson villa, within a few feet of the church, which is a triangulation point of the Government survey. The day was only partially clear. Light banks of cumulus clouds drifted at intervals down from the mountains, borne across by the trade winds which blow constantly at this season. The sun was entirely obscured during the first external contact and for several minutes thereafter. Before the first internal contact the clouds passed away and disclosed a perfectly clear image of the sun, with the planet almost completely inside the disc. The second contact was very satisfactorily observed. There was no appearance of the black ligament sometimes seen at the moment of separation. At the time of third contact (second interior) the sun was within a couple of degrees of the horizon. The image of the limb was of course quite unsteady. The phenomenon, commonly called "boiling," was very perceptible, but the bounding line of the disc was not hard to make out and the observation was tolerably good. The progress of Mercury was now followed with the eye for three minutes, when it was lost in the serrated and continually changing limb of the sun. At least two minutes before the time of last contact the form of the planet was utterly indistinguishable with my telescope. The times noted by mean time chronometer, Bond & Sons, No. 177, for the two contacts, were—

Second contact.	Third contact.
1^h 27^m 20^s	6^h 11^m 20^s

This chronometer was compared with the standard clock (Molyneux) at the Survey Office at 9 a. m. and at 8·30 p. m. of May 9. It was also compared the day before and for several days afterwards. These comparisons show that the trips to Waikiki had no significant influence on the rate. Applying to the observed times, the corrections to reduce Bond to Molyneux and those to reduce Molyneux to Honolulu mean time, we get for the times of contact as follows:

	Second contact.			Third contact.		
	h	*m*	*s*	*h*	*m*	*s*
Honolulu mean time,	1	26	45	6	10	42
Correction for longitude,	.	.	8	.	.	8
Waikiki mean time,	1	26	53	6	10	50
Observation by Mr. Lyons,	1	26	32	.	.	.
Observation by Dr. Marcuse,	1	27	3	6	11	22

Observations of the Transit of Mercury, May 9, 1891—Continued.

My telescope had an aperture of $3\frac{1}{2}$ inches, and the diagonal eye-piece used gives a magnifying power of about 100. The time as given by the standard clock depends on observations of both limbs of the sun in one position of the meridian telescope of the Government Observatory.

The transit of Mercury was observed to the nearest second of time. In order to test whether the corrections depending on the instrumental constants amounted to as much as half a second, star observations were made on a night preceding and following a solar determination in the usual way. The corrections to Molyneux are generally determined but once a week, which is quite sufficient for the requirements of the regular time service. From the star observations the following corrections were deduced for the time as given by the sun on May 9 when the circle was west:

Correction to observed *t*:

	s
For azimuth,	+0·2
For level,	+1·3
For collimation,	—1·0

The level correction was always taken account of in the solar observations, so that the outstanding sources of error give a correction of $-0^s.8$ to the regular time determinations. This has been applied to the times given above.

It may be mentioned as a matter of interest that the meridian telescope has not been adjusted since it was set up by myself in August, 1887, and that during the nearly four years intervening between then and now the azimuth has changed less than 3^s, the level less than 2^s, and the collimation not more than 1^s. Considering the size of the instrument and the high temperature to which it has been subjected in the daytime during this long period, this shows a remarkable stability in the pier.

APPENDIX No. 13.—1891.

ON OBSERVATIONS FOR THE VARIATIONS OF LATITUDE MADE NEAR HONOLULU, OAHU, HAWAIIAN ISLANDS, IN COÖPERATION WITH THE WORK OF THE INTERNATIONAL GEODETIC ASSOCIATION, AND ON DETERMINATIONS OF GRAVITY AND THE MAGNETIC ELEMENTS.

A preliminary report by E. D. Preston, Assistant.

Submitted for publication January 17, 1893.

This preliminary report will include notices of—

I. The international latitude observations from June 6, 1891, to June 25, 1892.

II. The measurements of the force of gravity on Oahu and Hawaii from June 9, 1891, to July 25, 1892.

III. The determination of the magnetic elements made at intervals from August 11, 1891, to September 9, 1892.

IV. Meteorological observations, including barometric determination of heights of Mauna Kea, from July 1, 1892, to July 27, 1892.

I.—Observations for the variations of latitude.

The following are the circumstances that led to this work: Some latitude observations made in Germany, at Berlin and Potsdam, and at Prague in Bohemia, showed a progressive yearly change in the results. As the motion was in the same direction for all three places, it became desirable to make a further study of the movement by observing at stations differing greatly in longitude; for if there had been a real motion of the pole, the effect on terrestrial latitudes would be in opposite directions on different sides of the earth. In order, therefore, to bring out the law of change most advantageously the International Geodetic Association took the matter up and proposed to send an observer to the Hawaiian Islands to make latitude determinations simultaneously with those executed in Europe. The difference of longitude of Berlin and Honolulu is $11^h 25^m$. The United States Government was asked to coöperate in order that the result of work, whatever it might be, should be checked independently by another observer and another instrument. This led to my assignment by the Superintendent of the Coast and Geodetic Survey, with instructions for some additional gravity, latitude, and magnetic observations during my stay in the islands.

I left Washington on April 18, 1891, in company with Dr. Marcuse, the European representative of the International Geodetic Association, arriving at Honolulu on the 8th of May, in the afternoon. Having been directed by the Superintendent to observe the Transit of Mercury, which took place on the 9th, provided we should arrive in time, the instruments were passed through the custom-house on the day of landing; the same evening the station was selected at Waikiki, 3 miles southeast of Honolulu, and the transit was successfully observed the following day.* Our next occupation was to choose a permanent site for the astronomical work. After several disappointments, the observatories were finally located on the property of Mr. J. F. Brown, of the Government Survey, who generously gave the use of the ground during the year.

Waikiki was preferred in order to avoid the clouds of Honolulu, as my experience there in 1883 and 1887 showed that place to be very unfavorable for continuous star observations. There were numerous unavoidable delays in getting material and workmen, and, as the programme was to begin work as soon after May 15 as possible, it was decided to concentrate all the force on one building and let one observer begin immediately. As I had several more instruments to set up than my colleague, it was deemed advisable for him to begin first; so that my observatory was not finished until five days after his. He began observations on June 1; my first ones were made on June 6. From this date on, the plan of work adopted was continuously carried out. Latitude observations were made in connection with Dr. Marcuse. Time was determined for the gravity work in the intervals between pairs of stars, and the pendulum was swung during the entire evening, concidences being noted at the beginning and end of the night's work, and whenever opportunity offered during the latitude and time observations. This gives a determination of gravity corresponding to each latitude determination, and will help to decide the question whether the change of latitude comes from a real motion of the pole or from transfers of large bodies of matter under the surface of the earth.

From June 6, 1891, to June 25, 1892, there were made 2 434 determinations of latitude; observations being made on 220 nights, as follows:

	Nights.	Latitudes.		Nights.	Latitudes.
1891			1892		
June,	20	212	January,	18	195
July,	14	156	February,	19	267
August,	20	254	March,	18	215
September,	11	155	April,	16	122
October,	11	124	May,	23	219
November,	15	169	June,	16	127
December,	19	219			
				220	2 434

* See a report of these observations in Appendix No. 12, 1891.

II.—Gravity determinations.

Before leaving for Honolulu I suggested to the Superintendent the feasibility of making continuous observations for the force of gravity. This was possible without increasing the expense of the work, and such observations were made at Waikiki every night that latitudes were observed. We thus have a series of nearly 200 nights of gravity determinations extending throughout the year. Time stars were observed before the first coincidence and after the last one, and as many observations as possible were made on the pendulum at intervals between the latitude pairs, so that in all there are not far from 1 000 measures of the force of gravity.

On June 15 the pendulum apparatus was taken down at Waikiki and mounted at Honolulu. As I desired to continue the latitude work at the former place as long as possible, the zenith telescope was left standing and the latitudes were continued on every clear night while preparing the stations in Honolulu. After the pendulum observations were in operation the Waikiki work was still carried on whenever possible to observe stars. The pendulum was observed during the day at Honolulu and stars obtained during the early evening. Then the trip was made to Waikiki (3 miles), and latitude continued until the end of the list.

On June 28 we left for Hawaii, the party consisting of Prof. W. D. Alexander, the Surveyor-general, Mr. W. E. Wall, Mr. W. W. Chamberlain, Mr. Louis Koch, and myself. At Waimea the party was joined by Mr. J. M. Muir, a volunteer observer, who rendered valuable service on the mountain both in triangulation and magnetic work.

The object of this trip was the determination of the force of gravity at the base and summit of Mauna Kea, the highest peak on the islands. The elevation is nearly 14 000 feet. Other observations were also made consisting of latitude, magnetic, meteorological, etc.

Landing at Kawaihae on the evening of June 29, this station was occupied before July 7. Observations were made for latitude, time, gravity, and magnetism.

From this point we passed to the plains of Waimea at an elevation of 2 600 feet. At this place animals were engaged for the ascent and packers hired. While making the necessary arrangements, two stations were occupied for magnetic observations. One of these had been occupied in 1872 by the Government Survey officers and the other was a new station at the end of their base line. This work was done at the request of the Surveyor-general.

On July 12 the party left for Kalaieha. The ascent is very gradual. The trail winds around the mountain, and after a journey of 35 miles we found ourselves at an elevation of 6 700 feet above the sea. From this point to the summit the path is rough and steep. Only 12 miles more travel were necessary to overcome the same vertical distance

that we had risen in traveling the 50 previous miles. A full series of observations was made at Kalaieha, but as this point lies just at the beginning of the cloud region the greatest difficulty was experienced in getting stars.

Only five pairs could be secured for latitude and the time determinations for gravity are rather weak. Much of the work was done during rain. The object glass was uncovered long enough to make the observation while the star was passing, and immediately after a pair was observed or after a half set for time the telescope was carried into the tent to be wiped and dried. Owing to the great difficulty of transporting baggage, no separate observatory tent was taken and the telescope was mounted in the open air.

At this point the party was reinforced by Mr. E. D. Baldwin, of the Government Survey, who had come up on the windward side, bringing some pack mules and a guide from Hilo.

We began the ascent from Kalaieha on July 19, with a pack train of twenty-two animals and eleven men. One of the donkeys that carried the magnetic instruments and some firewood became unruly and ran away. As we were enveloped in fog, he found no difficulty in escaping, and was only recaptured at 3:30 p. m., after eight hours' hunting by eight of the party. This necessarily deferred the trip one day, and another start was made at 7:40 the following morning.

We arrived at Waiau, over 13 000 feet elevation, late in the afternoon. About half the party made the ascent by 3 p. m., but as many of the animals were suffering from the rarity of the air and from the travel over the rough lava, it was impossible to urge them much, and many did not arrive until late; in fact, some did not get up at all, and from sheer exhaustion refused to go beyond about 12 000 feet. They were unloaded, and their loads taken by stronger mules that had already been to the top and unloaded.

A stay of five days and six nights was made at Waiau. The ranges of temperature were from 13° F. at night to 108° at noonday, the thermometer being in the same position for both readings.

The pack animals arrived from below at 11 a. m. of July 26. Everything was in readiness, and after two and one-half hours spent in packing the mules we started down. On the way we passed by Lilinoe, where in past times the natives had established a burial ground at an elevation of about 12 500 feet, and farther on we came to Keanakakoi (the ax-makers' cave), where before the introduction of iron a quarry had been opened for the production of battle-axes. The elevation of this point is over 12 000 feet.

We arrived at Kalaieha the same evening. Two days were passed here, repacking the instruments and putting the records in order. All the luggage was sent down the lee side of the island to Kawaihae, a distance of 50 miles, to be shipped to Honolulu. As it was desired to make magnetic observations at Hilo, Mr. Baldwin, Mr. Wall, and

myself left the party here. This could be done without increasing the time spent on the island, as we were able to take the same steamer that was to pass round the island and load the instruments at Kawaihae.

III.—MAGNETIC OBSERVATIONS.

The first of these were made on August 11, 1891, when engaged in the latitude observations at Waikiki. The date of occupation of this station was chosen so that all the work could go on together. At the time mentioned our astronomical observations extended from 7 p. m. to 11 p. m. With these hours for night work it was possible to make magnetic observations for all three elements during the day and allow no break to occur in the regular series for time, latitude, and gravity in the evening.

The second station was made at Kahuku, on the extreme north point of Oahu. This made it necessary for me to be absent from Waikiki from November 24 to November 29. Leaving Waikiki at 6 a. m. of the 24th, the distance to Waialua was made by 3 p. m., where lunch was taken. In the evening the remainder of the trip was made, and we arrived at Kahuku at 8 p. m., having ridden horseback more than 40 miles over a difficult road. On the following morning, November 25, observations were begun. They were completed on the 27th, and we were back in Honolulu on the evening of the 28th. Prof. Alexander accompanied me and kindly recorded these observations.

Honolulu was occupied on June 2, 3, and 4, 1892, at the same time that the Waikiki work was in progress. The subsequent magnetic stations, up to the time of the conclusion of the Mauna Kea work, were occupied in connection with gravity and latitude observations, and have already been described.

We arrived at Hilo on the evening of July 28, having passed thirteen consecutive hours in the saddle. The trail from Kalaieha is 35 miles long, and much more than half of it is over bare lava of the "aa" and "pahoehoe" types. No traveler attempts this trip without carrying horseshoeing implements, for the lava is of such a nature that the hoof of an unshod horse would be cut through in a few minutes, and nothing could induce the animal in that case to continue the journey. We saw the carcasses of a dozen horses that had been mercifully killed or unmercifully left to die of starvation.

Cocoanut Island was occupied at Hilo from July 30 to August 3, and we arrived in Honolulu on August 6. At the request of Prof. Alexander, the Surveyor-general of the Kingdom, I left on the next steamer for Kealakeakua Bay to re-occupy the magnetic station of Capt. Cook at Napoopoo. His observations were made more than one hundred years ago, and were finished just before the outbreak which cost the great discoverer his life. On the way back to Honolulu I stopped three days at Lahaina, and made magnetic observations

where De Freycinet had an observatory in 1819. Honolulu was again reached on August 27. Two more stations remained to be occupied, and on August 30 we left for Kauai. The work being done at Waimea I went on board the *Mikahala*. Learning that before returning to Honolulu she would go to Niihau I determined to make the trip and get one station on that seldom visited island. This neither increased the expense nor delayed my return, as otherwise it would have been necessary to wait at Waimea until the vessel came back.

IV.—Meteorological observations.

When it was decided to occupy the summit of the highest mountain in Hawaii, the occasion was taken to verify its height, as determined previously by Prof. Alexander. To this end barometers were read at the four mountain stations, Kawaihae, Waimea, Kalaieha, and Waiau. Simultaneously with this, barometric observations were made in Honolulu, and at Hilo and Waimea, on Hawaii. The wet and dry bulb thermometers were also read for the relative humidity, and the direction and force of the wind, the percentage of clouds, etc., were noted. On the summit the mercurial barometer stood at approximately 18·3 inches at a temperature of about 54° F.

On September 14 I took passage in the steamship *Australia* for San Francisco. Arriving on the 21st, I found orders from the Superintendent to measure the force of gravity at the Lick Observatory. This was done between September 28 and October 2, the time between September 22 and 27 being employed in getting the instruments through the custom-house and in repairing the pendulum apparatus, which was considerably out of order from the experiences on the top of Mauna Kea. On October 4 I started for Washington and arrived on the 16th.

In closing, I desire to express my obligations to the Surveyor-general, Prof. W. D. Alexander. Throughout my entire stay I was the constant recipient of professional favors. The observatories at Waikiki, the meridian mark on Makiki, and the transportation of the heavy outfit to the gravity station above the clouds, all bear testimony to his generous aid. It is due to the Hawaiian Government Survey to state that the greater part of the Mauna Kea expenses were borne by that Bureau.

The following table gives a summary of the season's work:

Summary of observations in the Hawaiian Islands in 1891–'92.

Station.	Island.	Date of occupation.	Class of observations.	Nights or days of observations.	No. of determinations.	Remarks.
		1891. 1892.				
Waikiki.	Oahu.	June 6–June 25	Latitude.	220	2434	
		June 9–June 11	Gravity.	199	827	
		June 9–June 11	Time.	202	202	
		1891.				
		Aug. 11–Aug. 13	Magnetic.	3	3	
Kahuku.		Nov. 25–Nov. 27	do.	3	3	
		1892.				
Honolulu.		June 23–June 25	Gravity.	3	57	
		June 15–June 27	Time.	10	10	
		June 2–June 4	Magnetic.	3	3	
Kawaihae.	Hawaii.	July 4–July 6	Latitude.	3	23	
		July 3–July 6	Gravity.	4	91	
		July 3–July 6	Time.	4	4	
		July 1–July 3	Magnetic.	3	3	
		June 30–July 7	Meteorology.	8		
Waimea.		July 8	Magnetic.	1	1	West base.
		July 9–July 11	do.	2	2	Old station.
		July 7–July 11	Meteorology.	5		
Kalaieha.		July 14–July 15	Latitude.	2	3	
		July 14–July 16	Gravity.	3	67	
		July 14–July 18	Time.	6	6	
		July 14–July 16	Magnetic.	3	3	
		July 13–July 18	Meteorology.	6		
Waiau.		July 21–July 25	Latitude.	4	55	
		July 22–July 25	Gravity.	4	81	
		July 21–July 25	Time.	4	4	
		July 21–July 24	Magnetic.	3	3	
		July 21–July 26	Meteorology.	6		
Hilo.		July 30–Aug. 3	Magnetic.	5	3	
Napoopoo.		Aug. 18–Aug. 21	do.	4	3	
Lahaina.	Maui.	Aug. 23–Aug. 25	do.	3	3	
Waimea.	Kauai.	Sept. 2–Sept. 3	do.	2	2	Latitude station, 1887, and transit of Venus, 1874.
		Sept. 5–Sept. 6	do.	2	2	Thorny Croft.
Nonopapa.	Niihau.	Sept. 9	do.	1	1	

In the column "Number of determinations," the figures indicate:

For latitude.—The number of pairs of stars.

For gravity.—The number of intervals, each giving one value for the period of oscillation of the pendulum.

For time.—The number of sets of stars, each one giving a correction to the chronometer.

For magnetic.—The number of determinations of all three elements—declination of the needle, the dip and the horizontal intensity, and time and azimuth.

The meteorological observations were made many times during the day. The barometer was read at the times of maximum and minimum, at 9 a. m. and 3 and 9 p. m. On the summit of Mauna Kea it was read more frequently.

APPENDIX No. 14.—1891.

REPORT OF AN EXPEDITION TO MUIR GLACIER, ALASKA, WITH DETERMINATIONS OF LATITUDE AND THE MAGNETIC ELEMENTS AT CAMP MUIR, GLACIER BAY.

By HARRY FIELDING REID,

Professor of Physics at the Case School of Applied Science, Cleveland, Ohio.

Submitted for publication December 10, 1891.

INTRODUCTION.

In the spring of 1890 a party was formed, consisting of Messrs. H. P. Cushing, H. McBride, R. L. Casement, J. F. Morse, C. A. Adams, and the writer, for the purpose of exploring and studying Muir Glacier, Alaska. All my companions rendered most efficient aid. Mr. Cushing took entire charge of the geological and meteorological observations. Messrs. Adams and Morse did most of the trigonometric work, while the writer did the plane table work, made the magnetic and latitude observations, and had general charge of the expedition. We established our camp, which we named Camp Muir, near the end of the glacier, on July 1, 1890, and remained there until the middle of September, mapping and studying the region.

Many of the necessary instruments were lent us by the U. S. Coast and Geodetic Survey. A list of them will be given at the end of this report.

General Geography.—The southeastern extremity of Alaska consists almost entirely of an archipelago of islands, which occupies a space nearly 350 miles long and 100 miles wide. These islands, large and small, are closely packed together, and the waterways between them are deep and narrow, and often form long strait canals. The islands are mountainous and precipitous, affording few landing places. Their slopes are densely wooded, mostly with spruce. The rough surveys of Vancouver, a hundred years ago, as revised later by Tebenkof and others, were, until 1867, largely relied upon as supplying the most accurate informa-

tion of parts of the coast. Since that year the explorations and surveys made by the U. S. Coast and Geodetic Survey, under the direction of Assistant Davidson, Acting Assistant Dall, and during the period from 1881 to the present time by officers of the Navy attached to the Coast Survey Service, have resulted in the publication of charts and Coast Pilots making known the more important channels and waterways with ample accuracy for all purposes of navigation. Southeast of the Alaskan boundary the islands become larger and the waterways wider. Cross Sound and Icy Strait form the northwestern boundary of the archipelago. From them two deep inlets, Linn Canal and Glacier Bay, stretch to the north and northwest, forming, with the Pacific Ocean, two peninsulas.

Tho great Fairweather group of mountains occupies the western part of the peninsula between Glacier Bay and the Pacific. The eastern part is occupied by another and much lower range, whose peaks rise about 1 800 metres above the sea. Their northeastern slopes are gradual, and are covered with large glaciers, some of which reach tide-water and discharge icebergs into Glacier Bay. Between these two ranges there seems to be a deep valley, which drains the eastern slopes of the Fairweather group. This is probably filled by a long narrow glacier discharging into Taylor or Dundas Bay.

Little was known of the peninsula between Glacier Bay and Lynn Canal before our expedition mapped its northern part, except that it is entirely made up of glacier-bearing mountains, whose peaks are from 1 800 to 2 400 metres high.

Northwest of Cross Sound the character of the coast changes abruptly; the coast line becomes continuous without outlying islands and broken by few inlets. Mountains of great height rise immediately from the water's edge. We can therefore topographically divide the southeast coast of Alaska into two regions; the line between them passes along Cross Sound, then follows the valley just northeast of the Fairweather range for 60 or 80 kilometres, beyond which point we know nothing whatever about it. This topographical difference seems to be accompanied by a geological difference. Mr. Russell has shown that the St. Elias Alps are of tertiary origin, and probably the Fairweather group belongs to the same range, though I believe it has not been at all explored. If this is true, the Fairweather Mountains are of tertiary origin, while the mountains about Muir Glacier, and probably the rest of the same topographical region to the southeast, belong to paleozoic and archean time. (*See* Nat. Geog. Magaz., Vol. IV, Supplements I and II to "Studies of Muir Glacier".)

Another difference is quite marked. Mr. Russell has found raised beaches about Yakutat Bay, indicating that the land there has risen, whereas the submerged trees in Muir Inlet show that this region is sinking. These striking facts seem to show that the valley between the Fairweather Mountains and Glacier Bay follows the line of an

Report of an Expedition to Muir Glacier, Alaska, etc.—Continued.

immense geological fault, which brings tertiary and paleozoic rocks into close juxtaposition. It is most unfortunate that we have no observations on the Fairweather Mountains that will enable us to confirm or correct this interesting indication.

Glacier Bay and Muir Inlet.—Glacier Bay itself has not been surveyed; its delineation in the Coast Survey charts is correct only in its general outline. It lies northwest and southeast and is about 65 kilometres long by 15 kilometres wide. There are a great many islands in the bay. The Beardslee Islands, which fill the eastern side for a distance of about 30 kilometres from its mouth, are made up, at any rate, in part, of modified glacial till, and are generally thickly wooded, as are also the shores in the lower part of the bay. The channels betweeen these islands are narrow, and often give one the impression of waterways cut through the land. The islands in the upper part of the bay are quite different; they are of solid rock, and are scored, polished, and rounded by glacial action; they occur singly, are usually elongated, and have the long axis parallel to the nearest shore. They, like the main land, descend abruptly into the water, and only at long intervals can even a small beach be found. In this part there are no trees. Several glaciers force their way down to the water's level and discharge bergs into the bay; most of them end in a narrow inlet two or three miles back from the bay proper. Muir Glacier is of this type; its inlet, which runs about north and south, has its southwestern terminus on Glacier Bay about 8 kilometres from the end of the glacier; the eastern shoreline rounds gradually into the bay without any well-marked headland. The inlet gradually narrows as we approach the glacier, being about 2·5 kilometres wide at its upper end. On each side are deposits of roughly stratified sands and gravels, covered with a thin layer of moraine debris. On the west side, these deposits form a comparatively level plateau from 45 to 60 metres high, which extends about 6·5 kilometres south of the present ending of the glacier, and is about 1·6 kilometres wide. Its surface bears a number of shallow lakes; and here and there deep ravines mark the position of former water courses. The western subglacial stream has cut a gorge through this plateau, and exposed the buried forest described by Prof. Wright.* For three-quarters of its length the plateau ends on the water side in precipitous bluffs, below which there is a narrow beach, only covered by the highest tides. On the east side the bluffs only extend for a kilometre or so; the upper surface of the deposit is not a plateau, but slopes gradually down to the bed of the glacial stream at the foot of the mountains. This stream empties into the inlet just below where the bluffs end. South of the stream the deposits slope gradually up from the beach to a height of about 120 metres against the mountain side.

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*Ice Age in North America, ch. III.

The inlet is quite deep. Prof. Wright reports a sounding by Capt. Hunter of 86 fathoms about 1 200 metres south of the present position of the ice-front. Capt. Carroll last summer (1890) found within 100 metres of the ice-front a depth of 120 fathoms. This does not necessarily indicate that the inlet increases in depth as we approach the immediate neighborhood of the ice, for the earlier sounding may not have been taken in the deepest part of the channel.

Muir Glacier.—Muir Glacier (see illustration No. 22) occupies a depression in the mountains about 60 kilometres long and from 10 to 15 wide. It is fed by a great number of tributaries, of which the First Northern, the Second Northern, and the Northwestern are by far the largest. These again are made up of many smaller glaciers. The general slope of the surface is about a degree and a quarter. This is based on a barometrical reading made between Tree Mountain and Granite Cañon. The appearance of the glacier to the northwest indicates that the slope there is about the same. The total area drained by this system is about 2 250 square kilometres, the actual surface of the ice being about 1 000 square kilometres. The area draining into Muir Inlet is about 2 000 square kilometres. Most of the precipitation which falls on this area flows off as water in the subglacial streams; the rest, compressed into ice, is forced through the narrow gateway about 4 kilometres wide into the inlet, where the glacier terminates in a vertical wall of ice, varying from 40 to 65 metres above the water's surface, from which large masses are continually separating to become icebergs. As already said, the depth of the water is in places 120 fathoms or 220 metres, and as this is not enough to float a mass of ice which rises as high above the water as Muir Glacier does, the ice must reach to the very bottom, and must attain a thickness of 275 metres. The actual length of the ice-front facing the water is 2 800 metres. On each side the glacier sends forward a wing, which rises in the shape of a wedge over the stratified sands and gravels of the shore. The upper surfaces of the wings, like the ice-front, are about 60 metres above the water level. This applies only to the parts of the wings overlooking the inlet; the parts nearer the side mountains are 15 to 30 metres lower, and here the ice ends like an ordinary alpine glacier. The wings are fringed by treacherous quicksands, which support large stones and look firm enough, but the tourist who steps upon them carelessly will quickly sink in over his ankles. These quicksands are composed of fine glacial mud, thoroughly soaked with water from the melting ice.

The ice-front has a wonderful coloring. Places from which ice has recently broken off are deep blue, sometimes almost black. This color lightens under exposure to the air and sun, and in a few days becomes pure white. All stages are represented in the ice-front, which therefore shows all shades of blue in striking variety.


MUIR GLACIE
ALASKA
Surveyed by H. F. Reid in 1
Gable Mt.
Glacier
Berg Lake
Valley
Mt. Young
Heights above mean-tide in feet
Snowfields and small steep g
Approx. contour lines on the
Statute Miles.
Kilometres.
136° 30'
40'
10'
59° 00'
50'


MUIR GLACIER
ALASKA
Surveyed by H F Reid in 1890
Heights above mean tide in feet.
Snowfields and small steep glaciers
Approx. contour lines on the ice
Statute Miles
Kilometres
MUIR GLACIER
N.W. Glacier
Glacier
Gable Mt
Black Mt
Snow Dome
Granite Canyon
Main Valley
Berg Lake
W. Tributary
Pyramid Pk
Mt Case
Mt Wright
Mt Young
MUIR INLET
GLACIER BAY

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Tributaries.—Beginning at the right (see the illustration), we find three tributaries coming in from the southeast. The Dirt Glacier sweeps around in a great curve from behind Mount Wright; its lower part is completely covered with débris for fully 2·5 kilometres from its mouth; above this the glacier is particularly clean. The White Glacier, which joins the Muir just beyond Mount Case, is remarkably beautiful. Arising in a circle of snowy mountains, it flows down a deep and narrow valley at an angle of about 10°, its very white surface marked by the wonderfully symmetrical parallel curves of three or four dark moraines. It is about 6·5 kilometres long and 0·8 wide. A little farther is the Southeastern Tributary, fed by a number of smaller glaciers. This glacier is not hemmed in by mountains, but crosses a divide to the east of a_{15}, over which the ice flows into some valley on the other side. This divide has an altitude of 600 or 750 metres. About 15 kilometres southeast of our camp a large glacial stream discharges into Glacier Bay. It must drain the southern side of the mountains which bound these three tributaries. A little farther to the east is Main Valley, which, though it probably once contained a tributary, is now an outlet of Muir Glacier. The ice flows down this valley in a stream 3 miles wide, but apparently with a very slow motion. A few miles down the valley the ice ends in a high wall facing Main Lake, into which it occasionally discharges a berg. The stream draining this lake flows through a broad flat valley of sands and gravels to the southeast, and finally empties into Lynn Canal. The three valleys entering the eastern side of Main Valley also have flat, gravel-covered floors, through which rush the streams from the snow fields and small glaciers at their heads. Two of these valleys are beyond the present termination of the glacier. Formerly the ice must have extended across their mouths, hemming them in and converting them into lake beds. The upper valley is now in just this condition. The lake which occupies it has been called Berg Lake on account of the great number of icebergs in it last summer (1890). Just to the north of the entrance to Main Valley lies the Girdled Glacier, so called on account of the moraine which completely surrounds it; it can be seen from the end of Muir Glacier, but is so fore-shortened that one would not suspect that the visible portion is 5·5 kilometres long. To the west and separated from the Girdled Glacier only by a narrow ridge is Granite Cañon, a deep gorge with precipitous sides running about 13 kilometres into the heart of the mountains.* The ice slopes downward into the cañon, whose drainage, however, must be back under the ice; for although I was unable to see every point of the ridge which closes in the back of this valley, I could see sufficient of it from different points of observation to convince me that no part of it was less than 300 metres above

* This was named from the crystalline nature of the rock, which, however, is not a true granite. (See paragraphs under heading *Geology*.)

the floor of the valley. This curious condition seems to be due to the fact that this valley once contained a tributary glacier, which on account of the present smaller supply of ice, and the reflection of the heat from the northern side of the cañon, has melted down more rapidly than the surface of the main glacier; so that now, although this I could not see, the glaciers draining into this valley are probably entirely separated from the ice entering at its mouth. The tributaries so far mentioned supply none of the ice which forms ice front in Muir Inlet; all the ice coming from them that does reach the end of the glacier is compressed into about 750 metres between the ice front and the mountain to the east. If a line were drawn from station H to the eastern side of the first Northern Tributary, and a second line to the northwest at right-angles to the first, the sources of all the ice which reaches the ice front would lie in the quadrant between them.

The first and second Northern Tributaries, and the main glacier present no striking peculiarities. These are immense streams of ice fed by innumerable smaller glaciers; the mountains which rise between them and through them are deeply laden with snow, and toward the northwest seem to raise only their summits through the icy sea. The extremities of these branches could not be clearly determined, although they all seem to connect by low divides with valleys beyond. The Northwestern Tributary heads in two beautiful white conical-looking mountains, which we have called the Snow Cones. A part of its ice flows over the divide between l_3 and l_5 and joins a large glacier which is probably identical with the one which enters the head of Glacier Bay. The Western Tributary supplies no ice to the ice front; moreover, its snow fields are too small and too low to supply ice for a glacier of its width, and it is evidently melting away. At its western extremity it crosses over a divide and flows into a valley beyond.

The mountains immediately surrounding Muir Glacier are not high, the highest peaks being between 1 800 and 2 400 metres. The mountains which first attract the attention of the visitor are Mount Wright,* Mount Case,† and Pyramid Peak; the first two, by their jagged crests, seamed by snow couloirs; the last by its symmetrical form; all three by their proximity. The more distant mountains seem to lack somewhat in individuality; this is largely due to their distance, for they are from 25 to 50 kilometres away. All is bare and bleak, and the scenery is entirely lacking in picturesqueness. If we go out on the ice as far as H the three bold peaks of Mount Young show themselves over Tree Mountain; and the beautiful Snow Cones at the head of the Northwestern Tributary can be seen.

Drainage.—The principal drainage of the glacier is into Muir Inlet. On each side of the inlet a large stream issues from the end of the ice

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* Named after Prof. Wright, who spent some time studying Muir Glacier in 1888. He has described it in his Ice Age in North America.

† After the Case School of Applied Science, Cleveland, Ohio.

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at a number of points, and after a rapid course of between 1·5 and 2·5 kilometres empties into the inlet, forming quite a large delta. These streams were about 10 metres wide and half a metre deep. Their course is so swift that they roll down stones as large as one's fist; but the principal material that they carry off is in the form of fine mud. We used this water largely in our camp, and found that although most of the mud would precipitate when allowed to stand for a few hours, still the water remained quite turbid even after three or four days. The muddy character of the water in the inlet a little west of the middle of the ice front shows that another stream must discharge in that region, either under or through the ice. A small part of the drainage of the glacier passes down Main Valley, but this does not amount to very much. I think the principal sources of the stream in this valley are from the snow fields and smaller glaciers on its sides.

Geology.—The geological observations were undertaken by Mr. Cushing. Some rocks collected near the glacier were submitted for microscopical examination to Dr. George H. Williams, of the Johns Hopkins University. The following is extracted from their reports.* The rock bordering the glacier on the south and southeast is slate. It has a very variable, but in general, high dip to the southwest, and is much faulted. On the east side of Muir Inlet this is overlaid conformably by limestone, the junction reaching tide water, about 13 kilometres southeast of the glacier. The southwestern shore of Glacier Bay and the islands near it are composed of this rock. In one of these islands Mr. Cushing found fossils which make it probable that the limestone and underlying slate are of paleozoic age.

The western part of the glacier's basin consists of quartz diorite, light gray in color. The line of junction with the slates, beginning at the small glacier on the northern shoulder of Pyramid Peak, runs easterly, passes between the F and K ridges, and then between H and I. It then turns to the northwest, passing between g_5 and f_2. The northern mountains are diorite, bordered on the south by a narrow band of slate. The eruptive rocks (the diorites and quartz diorites) are full of dikes running in all directions. The eruptions occurred at two or more periods. Some of these rocks are very old, and closely resemble archean terranes occurring in the Cordilleras further south. Although the difficulties of travel prevented Mr. Cushing from examining the region very thoroughly, he thinks we have to do here with a tilted block dipping towards the southwest, but much distorted by minor folds and by faults.

Changes going on.—Many indications show that Muir Glacier is becoming smaller, and considerable changes may be expected before many years. Main Lake and Berg Lake are now separated by a very

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* These reports are given in full in "Studies of Muir Glacier," Nat. Geog. Mag., Vol. IV.

short distance, and it will not be long before they unite. This will result in the draining of Berg Lake, which event will probably be marked by a flood. The melting of the ice in Main Valley must be rapid, for the great extent of its termination there presents a large surface for melting. When this termination has receded 4 or 5 kilometres, and the surface of the ice has sunk 60 to 100 metres, the ice from the first northern and from the southeastern tributaries will probably be in part deflected into Main Valley.

The small lake which occupies a lateral valley opening into Granite Cañon will probably extend as the ice diminishes, and perhaps occupy a large part of the cañon itself.

Prof. Wright has kindly sent me some photographs which he took of the glacier in 1886. By comparing these with our photographs we can readily fix on our map, within 100 metres, the position of the ice front at the time of Prof. Wright's visit. This shows that in the four years from 1886 to 1890, the western end of the ice front has receded 1 100 metres and the eastern end 900 metres. The center has also receded about 1 100 metres, so that the average recession of the ice front is about 1 000 metres in four years. Prof. Muir writes me that the notes of his first visit to the glacier in 1879 show that the ice then extended almost to our station D. The rate of retreat deduced from this accords fairly well with that given above. The ice front, therefore, must have extended as far as island C twenty years ago. Below C, I think the retreat was more rapid, for there the glacier presented a much wider front to the water, from which a correspondingly larger quantity of ice must have broken off. And this could hardly have been entirely compensated for by a greater velocity of flow, on account of the many obstructions in the neighborhood of the present position of the ice front. It does not seem at all incredible that the ice from the various glaciers of Glacier Bay may have united to fill a large part of the bay a hundred years ago. Prof. Wright's interpretation of Vancouver's description seems perfectly in accord with what our observations would lead us to conclude.

The retreat is probably not regular, but is faster some years than others; and even varies considerably at different parts of the same season. For two or three weeks in August (1890) there was scarcely any fall of ice; in the two weeks following the fall was so rapid that a great bay, fully a quarter of a mile deep, was made in the eastern part of the ice front, which was, before this, only slightly concave. I have collected on the map the positions of the ice front at several periods; this shows the retreat at a glance, much better than it can be described in words. The changes in the shape of the front will also be evident.

The present rate of recession of the ice front in Muir Inlet, a kilometre in four years, will probably be exceeded in the near future, for it has reached a point where the conditions change. The deposits which support the wings are almost at the water's level at the ice

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front, and slope down at an angle of 6° or 7°; a little further back they will be below the water's level and the ice front will be broader, resulting in an increased amount of loss by breakage, and hence a more rapid retreat. Ten or fifteen years will probably see the Dirt Glacier on the east and the Western Tributary on the west, entirely separate from the main ice stream. The middle part of the valley which connects Muir Inlet with the upper part of Glacier Bay is now occupied by a small glacier without feeders, evidently the remains of a much larger body of ice. It probably derived its supply principally from the main body of ice which formerly filled the bay. This glacier, which we called the Dying Glacier, is rapidly melting away; in fifteen or twenty years I think its bed will be empty. The maps I have made will enable us to determine with considerable accuracy the amount of these changes in the future. I should, however, say that although the northern end of Main Lake is in its right place, the southern end is only approximately determined. The ends of the Dying Glacier are also only approximate.

THE SURVEY.

I.—BY TRANSIT.

The west side of the inlet was the best place for measuring our base line, as it offered a pretty long stretch of fairly level ground. The base line was measured on July 5, with a 30-metre steel tape (No. 23 U. S. Coast and Geodetic Survey).

Wooden stakes were driven into the ground, and into the top of each was driven a tack; the measures were all made from the north edges of the tacks. The tape was stretched by a spring until the tension was 16 pounds. Where the ground sloped, the tape was held as nearly level as possible, and plumb bobs were used to project the tape upon the edge of the tack. The base was measured twice, first from B to A, and then from A to B. The two values obtained were 962·301 and 962·330 metres. This close agreement shows that the measures were carefully made; and the average adopted, 962·32 metres, is probably not in error by 5 centimetres. The temperature of the air was 12·5° C., and would cause but a slight correction if the tape, as usually made, were correct at ordinary temperatures. No temperature correction was introduced. White flags were planted at the ends of the base line and the stations called B (north end) and A (south end). The stations A and B were then determined trigonometrically. Angles were taken from these stations and from D, Camp, E, and K. The transits used were Casella 120 and 3123, having 2¾-inch horizontal and vertical circles reading to minutes by two verniers, and telescopes magnifying 5½ times. The angles were measured several times; the sum of the three angles of the various triangles differed on an average about 2′ from 180°. The excess or defect was divided between the three angles,

but no attempt was made to make the sum of the angles at a particular station equal to 360°. The points L, M, b_4, c_2, were also determined trigonometrically, but the transit was not set up at those points. The following are some of the distances thus determined (A—B is the base line measured):

	Metres.		Metres.
A—B	962·32	D—M	1075·6
E—D	2492·2	E—M	1973·2
D Camp	819·26	M—L	2444·7
E Camp	2201·2	E—$b4$	23713
D—L	3091·0	E—$c2$	28865
E—L	4110·2		

The distance D—E was determined through the four triangles B, D, E; K, D, E; Camp, D, E; and A—B, D, E; the other two sides of each of these triangles having been already determined. The average gives 2492·2 as in the table, which is probably true to the fourth figure. At E and at D cairns of stones were made surrounding the flag. These cairns were about four feet high, and were made of the largest stones that we could move, so piled up as to hold the flags firmly in their midst. I think they will remain if unmolested five or ten years, and will serve to connect our map with any future surveys that may be made in this region. If these cairns should not last I think the two peaks, Mount Wright and $c4$, would make the best points of connection. The former on the east side of Muir Inlet can not be mistaken; the latter is a sharp peak with symmetrical shoulders, and when seen from the end of the glacier is slightly to the west of the entrance of Granite Cañon. It is the highest peak in its neighborhood.

The meridian line was determined near our camp in connection with observations for magnetic declination, but it was not determined at any of our trigonometric stations, and therefore we must determine the orientation of our map graphically. This gives for the direction of the line E—D, N. 41° 43′ E. (astron). The error is probably not more than 5′.

Altitudes were determined trigonometrically with respect to Camp Muir, and 8 metres (the estimated height of the latter above mean tide) added. The following are some of these altitudes:

	Metres.		Metres.
Camp Muir,	8	Mount Case,	1 679
E,	271	Wright,	1 507
D,	32·5	$b4$,	1 678
A,	53	$c2$,	1 995
B,	59	$d2$,	2 175
Pyramid Peak,	1 240	$d4$,	1 473

We expected to determine many altitudes by simultaneous observations of the barometer at camp (mercurial barometer 1738, Coast and Geodetic Survey) and of the aneroids at other points. But the latter instruments worked so unsatisfactorily that few of our barometrical altitudes were reliable. Only the reliable ones have been entered on the map.

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II.—BY PLANE TABLE.

The instrument used was Plane Table No. 81 of the U. S. Coast and Geodetic Survey. The table itself was 39 by 49 centimetres. The top, alidade, and tripod complete weighed about 40 pounds, and was very clumsy to carry.

The scale of the map was 1–99300. This was changed to 1–100000 for the final map. I have carefully abstained from filling in uncertain portions of the map conjecturally; I have, however, in some places added with dotted lines the ridges or peaks whose positions were roughly determined, also the boundaries of some small tributary glaciers, when the positions of the surrounding ridges made it probable that no serious error could be made. Contour lines of 200 feet were added on the glacier to show the general shape of its surface, but they pretend to no accuracy.

The survey was begun at E and H. The point H, though not determined trigonometrically, had its position fixed as soon as some trigonometric stations were plotted in. The plane table was also set up at Camp, D, L, M, O, P, R, N, S, T, and V; the positions of all these stations except the first four being determined by the three-point method, by aid of mountain peaks, which had already been plotted in. The points determined by plane table or trigonometrically are marked thus: ⊙, on the map. I do not think any of these points are out of their true position by 1% of their distance from E. At each of the stations V, O, P, R, N, and T, a number of photographs were taken in different directions. These have been very useful in working up details of topography, and in some instances have served to fix with considerable accuracy the position of certain peaks and thus the direction of some ridges. I have also made a map* of the northern part of the Muir Inlet on a scale of 1–20000. This map shows pretty well the general topography of this region, and also the position of the ice-front at various dates. It also shows where we planted our flags for measuring the motion of the ice. This work was carried out with great care. The greatest velocity we found was 2.2 metres a day for Flag 6^1. The side flags showed scarcely any motion.

Geographical position.—The latitude of our camp was determined by the following observations on the meridian altitude of the sun, made with the Casella $2\frac{3}{4}$-inch transit No. 120:

Date.	Station.	Latitude of station.	Latitude of Camp Muir.
1890.		° ′	° ′
July 13	Camp Muir,	58 49·75	58 49·75
16	E,	58 50·25	58 49·75
17	K,	58 50·50	58 49·50
Sept. 8	Camp Muir,	58 50	58 50

* See Nat. Geographic Magazine, Vol. IV, Plate 15.

This gives an average of 58° 49′.7 for Camp Muir. Our instruments read to minutes, so that this average can not be relied on closer than a half minute, though I do not think the error is greater than this. This would make the latitude of E 58° 50′.5.

No satisfactory determination of longitude was made. When we first went into camp the chronometer was unfortunately allowed to run down; and when we left, it stopped without any apparent reason. An attempt was made to determine longitude by comparing our chronometer with those of the steamers of the Pacific Coast Steamship Company, which brought tourists every week to see the glacier; but these chronometers differed so much among themselves that no reliance could be put on the result.

Mr. Junken, of the Coast Survey, by reference to the best map of the region, which is somewhat conjectural, has given me as the longitude of our camp 136° 8′ west of Greenwich, which he thinks is not in error more than 5′. I have adopted 136° 5′ west.

The eastern limit of the region surveyed must lie between 12 and 20 kilometres from the shore of Lynn Canal, and probably the mountains on the east of our map are visible from Sullivan Island. Davidson Glacier must have tributaries in the mountains which close up Granite Cañon. Whether or not one of its tributaries connects by a comparatively low divide with the First Northern Tributary of Muir I can not say; but it does not seem impossible. If there is any such connection between these two glaciers, the point indicated is where it will undoubtedly be found.

Magnetic observations.—These were made with the Bache Fund Magnetometer and Dip Circle No. 12 (of about 24 centimetres diameter), both belonging to the Coast and Geodetic Survey. The magnetometer was not adapted for determining deflections, but only for declinations and oscillations. For the latter a mean time chronometer (No. 1285, Coast and Geodetic Survey), was used. The moment of inertia was determined in the field. For this purpose a special stirrup was made. The upper bar of the stirrup was cylindrical, 2 millimetres in diameter, and carried two small brass cylinders, which could slide on it so as to press against stops near the center of the bar (cylinders "in"), or against stops at the ends of the bar (cylinders "out"). The moment of inertia of the system could thus be altered by a definite amount (the increase was about four-fifths of the moment of inertia with cylinders "in") without changing the mass. The masses and distances between the centers of mass of the cylinders, "in" and "out," were determined in the laboratory before starting on the expedition.

The variation of magnetic moment with temperature was determined. Two series of observations gave, respectively, for the coefficient of variation for 1° centigrade, ·00073 and ·00077. The mean was adopted. The magnetic moment of the magnet was determined some time after our return; and I do not think the values of the horizontal and total forces can be relied on more closely than 1 or 2 per cent.

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Quantities given in this report are in Coast and Geodetic Survey units (C. G. S). In the observations for declination, the astronomical meridian was determined by afternoon observations on the sun.

Special tents were erected for the magnetic instruments at Camp Muir. The magnetometer was 80 and the dip circle 60 metres from our tents. During the observation with the former the latter was about 100 metres distant.

Magnetic observations at Camp Muir, Glacier Bay, Alaska.

Date.	Declination.*	Daily approximate range.	Dip.	Horizontal intensity.	Total intensity.
1890.	° ′	′	° ′		
Aug. 22				·150	
23			75 49·8		
Sept. 5			75 51·7		
8	— 30 27·8	6·9			
9	— 30 26·1	8·4			
10	— 30 24·1	5·4			
Mean,	— 30 26	6·9	75 50·8	0·150	0·614

*The negative sign means easterly declination. The observations were made by the writer.

Meteorological.—Regular observations were made under the direction of Mr. Cushing, and a complete record sent to the U. S. Signal Service. The barometer used was No. 1738 of the Coast and Geodetic Survey. The maximum, minimum, wet, and dry bulb thermometers were lent me by Prof. Whitman, of Adelbert College. The rain gauge was lent by the Signal Service.

A short summary of these observations is appended.*

1890.	Temperature. (Fahrenheit scale.)			Barometer. (Inches.)			Rainfall.	Mean humidity.
	Mean.	Max.	Min.	Mean.	Max.	Min.		
	°	°	°					
July.	45·2	63·1	35·4	30·089	30·335	29·565	3·06	82·2
Aug.	45·1	63·9	27·2	30·123	30·418	29·787	4·88	83

LIST OF INSTRUMENTS LENT BY THE U. S. COAST AND GEODETIC SURVEY.

Two Casella Theodolites (Nos. 120 and 3123).
Two Telemeters (No. 81).
One 20-metre Steel Tape (No. 23).
One Plane Table (No. 81).

* For an account of other observations made on this expedition see Studies of Muir Glacier in the Nat. Geog. Mag., Vol. IV.

One Bache Fund Magnetometer.
One Mean Time Chronometer (No. 1285).
One Dip Circle (No. 12).
One Artificial Horizon (No. 30).
One Mercurial Barometer (No. 1738).
One Prismatic Compass (No. 108).
Two Draw Telescopes (Nos. 114 and 116).
One Clinometer (No. 3).
Two Negretti & Zambra Deep-Sea Thermometers (Nos. 66727 and 57080).
Two Casella Aneroid Barometers (Nos. 1098 and 2738).

The telemeters, artificial horizon, and deep-sea thermometers were not used.

In addition to these a transit and several other instruments belonging to the Case School of Applied Science, and a number of thermometers, aneroids, compasses, etc., belonging to various members of the expedition, were taken with us.

MAGNETIC OBSERVATIONS AT CLEVELAND, OHIO, 1891.

The following observations of the magnetic elements were made at Cleveland on April 6 and 26, May 30 and 31, and June 1, 1891. The station was the pier in the grounds of the City Hospital, which forms the north end of the meridian line laid down by the U. S. Coast and Geodetic Survey. This is the station occupied by the Coast Survey party in 1871 and 1880. It is not far from the hospital building and within 200 yards of the railroad. A passing train did not seem to deflect the needle more than a minute of arc.

The instruments used were Dip Circle No. 12, and the Bache Fund Magnetometer, both belonging to the Coast and Geodetic Survey. A small tent was erected to protect the instruments from the wind and rain.

The magnetic moment of the magnet was determined at the Case School of Applied Science April 6 and on May 26. The needle was oscillated again at the same point on June 9, and the product mH (from the two sets of observations) differed about 1 per cent. This is within the limit of errors of observations. The stirrup supporting the magnet with the two movable cylinders was the same that was used in the observations at Camp Muir, Alaska, in the summer of 1890.

The dip was determined on May 31, and June 1, the values obtained being 72° 34′ and 72° 44′ respectively; mean 72° 39′. This is less than the former values (1880) obtained here by nearly half a degree, but only 11′ less when compared with the observations of 1888 as determined by the U. S. Coast and Geodetic Survey. The secular change is diminishing the dip.

Report of an Expedition to Muir Glacier, Alaska, etc.—Continued.

The meridian line laid down by the Coast and Geodetic Survey was used, and no astronomical observations were made for declination determinations. These were obtained from maximum and minimum elongations.

Declination obtained.

Date.	Mean declination.	Apparent daily range.
1891	° ′	′
May 30	2 18·4 W	16
May 31	2 18·3 W	10
June 1	2 19·0 W	9
Mean	2 19 W	12

This declination is about one-third of a degree greater than predicted in Appendix 7, U. S. Coast and Geodetic Survey Report for 1888, p. 264, but only 12′ greater than the revised expression* for the secular variation sent me from the Survey Office, and which includes my observation.

The horizontal intensity was found from observations on April 6 and 26 to be ·1833 and ·1825, average 0·183, which is probably not in error more than 1 or 2 per cent. The total intensity is 0·614 of a dyne.

The nearness of the hospital, the iron railings around the grounds, and the railroad, now make this station an undesirable one for magnetic observations.

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*$D = +0\overset{\circ}{\cdot}77 + 2\overset{\circ}{\cdot}53 \sin. (1\overset{\circ}{\cdot}3\, m - 21\overset{\circ}{\cdot}6)$, where m = year of observation—1850.

APPENDIX No. 15—1891.

DETERMINATIONS OF GRAVITY WITH THE NEW HALF-SECOND PENDULUMS OF THE COAST AND GEODETIC SURVEY AT STATIONS ON THE PACIFIC COAST, IN ALASKA, AND AT THE BASE STATIONS, WASHINGTON, D. C., AND HOBOKEN, N. J.

By T. C. MENDENHALL, Superintendent.

Completed for publication June 25, 1892.

In previous reports* the operations of the Survey in the determination of the force of gravity are presented in more or less detail. The methods in use were essentially those that had found favor in Europe as well as in this country during the last half century. The work was for the most part done under the direction of C. S. Peirce, assistant, who made numerous and important contributions to both the theory and practice of gravity research. The active interest of the Survey in this subject began about 1873.

The numerous and often extensive discrepancies between geodetic and astronomical positions indicated the importance of and necessity for the investigation, and the bearing of the results upon geological problems adds additional interest to it. Much valuable experimental work was done and a number of stations occupied, including several in the old world, from the beginning of the work up to 1890. Some form of pendulum whose period was approximately one second was used, together with a clock having a seconds pendulum; the method of coincidences and, for a few years, that of chronographic registration having been adopted in determining the period of the gravity pendulum. Reversible pendulums were generally made use of, but the measurements were in the main differential and not absolute.

A serious difficulty in the way of continuing the investigation on this basis was its cost, when considered in connection with the number of stations occupied. The instrumental outfit of a party was large and

* Annual Reports for the following years: 1876, Appendix No. 15; 1881, Nos. 14, 15, 16, and 17; 1882, No. 22; 1883, Nos. 17 and 19; 1884, Nos. 14, 15, and 16; 1885, Nos. 16 and 17; 1888, No. 14; 1890, No. 12, and 1891, No. 13.

not easy to transport; much was required in the way of the preparation of a station, and thus a single determination involved the expenditure of so much time that it was extremely desirable to devise some means of more rapid working, especially if this could be done without material sacrifice of that accuracy which the nature of the problem demanded.

It was agreed that a great reduction in the magnitude and complexity of the instrumental outfit of a party could be made by using a pendulum vibrating in a half second, and substituting a chronometer for the clock. A short pendulum had already been used with success in Europe by Von Sterneck, and the chronometer, which commends itself especially by its great portability, had been used instead of a clock by many experimentalists, both in this country and Europe.

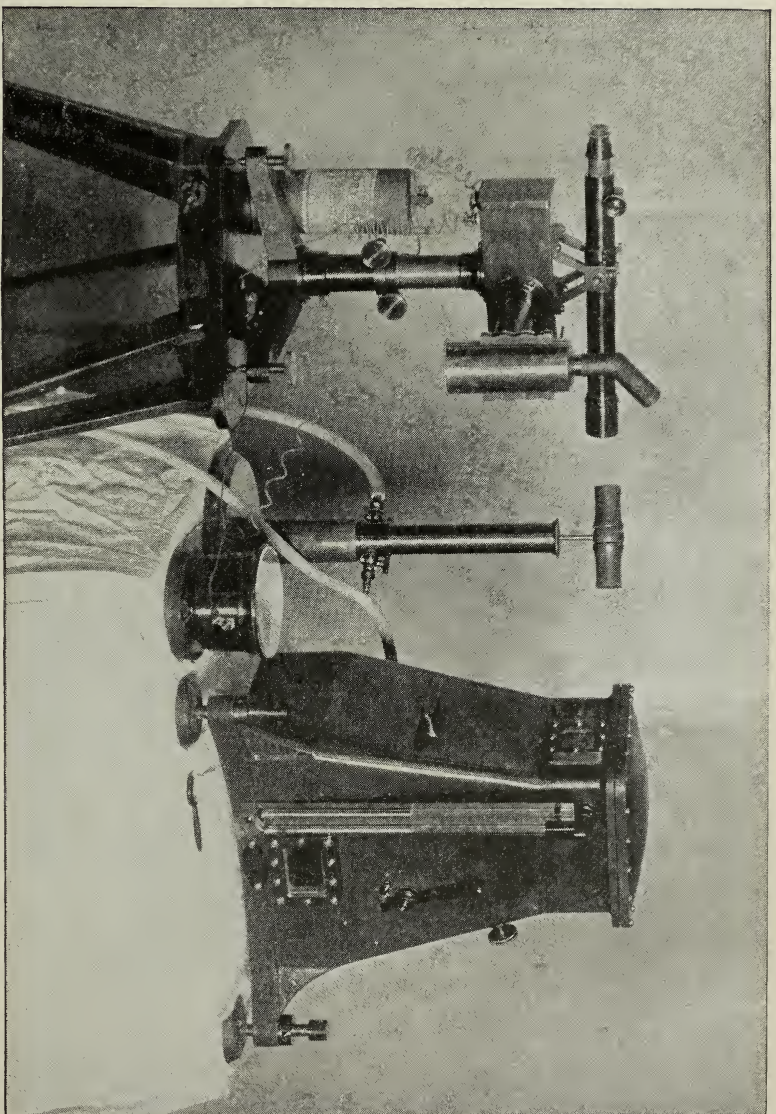
It seemed altogether wise to make use of the method of coincidences in measuring the period of the pendulum, and also that some optical method of doing this was preferable to any other. It was determined that invariable non-reversible pendulums should be used, except at a limited number of base stations, where absolute values of the force of gravity should be obtained by the use of reversible pendulums or by some other method.

In the elaboration of the plans for the work many valuable suggestions were secured from Mr. C. A. Schott, Mr. Edwin Smith, and Mr. E. D. Preston, assistants, the two latter having had large practical experience in gravity work; and in designing and constructing the apparatus the services of Messrs. Smith and Preston, together with Mr. E. G. Fischer, chief mechanician, and Mr. G. R. Putnam, aid, U. S. Coast and Geodetic Survey, were invaluable in securing the realization of the proposed improved devices, as well as in the suggestion and invention of many of them. A number of experimental studies of the use of the short pendulum were made by Mr. Preston, and the final result was the adoption of the form of apparatus, a detailed description of which has been prepared by Mr. Putnam, and is as follows:

DESCRIPTION OF APPARATUS.

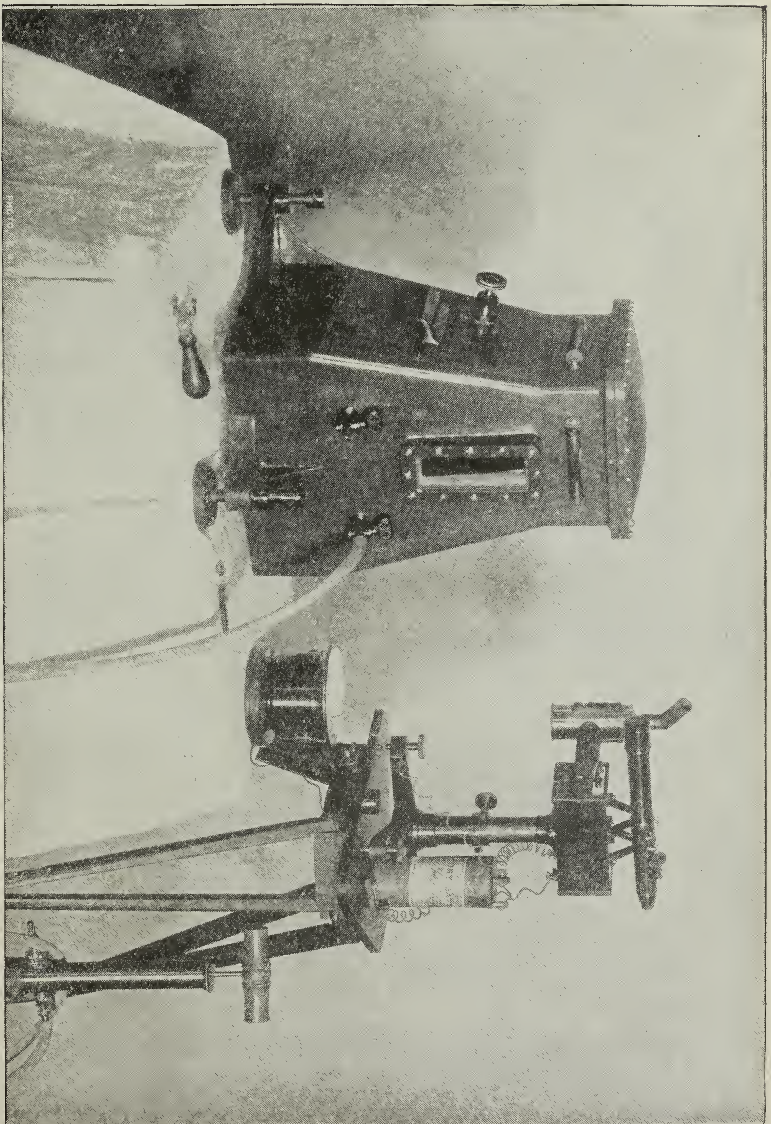
The new pendulum apparatus consists of a set of three quarter-metre pendulums, a dummy or temperature pendulum, an air-tight receiver in which the pendulums are swung, a flash apparatus, wherein an electromagnet in the circuit of a chronometer moves a shutter and throws out a flash of light each second, a telescope for observing, mounted above the flash apparatus, and various accessories, such as small air pump for exhausting receiver, break-circuit chronometer, barometer, batteries, etc. These instruments are shown in the accompanying illustrations,* as follows: Nos. 23 and 24 show the complete apparatus (except barometer) from opposite sides. No. 25 shows the dummy on the left

* The small letters refer to the various parts in illustration No. 26.



HALF-SECOND PENDULUMS.

Side view (right) of receiver, flash apparatus, etc.



HALF-SECOND PENDULUMS.

Side view (left) of receiver, flash apparatus, etc.

Determinations of gravity with the new half-second pendulums—Continued.

and the three pendulums on the right. In Fig. 2 the pendulum is shown suspended from the planes on which it swings (the plate being removed from the receiver), and in Fig. 4 the handle and manner of lifting the pendulum are represented. No. 26, Figs. 4 and 5, are side elevations (one-quarter full size) of the flash apparatus and receiver, with the sides cut away so as to exhibit the arrangement of the interior. Figs. 6 and 7 are sections (twice full size) on a vertical central line of the front of the flash apparatus box, to show the movement of the shutters, as will be further described.

The receiver.—The body of the receiver is a heavy brass casting, with walls 7 millimetres thick, and of inside dimensions 17 centimetres square at the top, 21 by 28 centimetres at bottom, and 38 centimetres high. The cover (k) makes an air-tight joint when a little tallow is applied to the contact surfaces, and may be screwed down when necessary. A portion of the main casting forms a solid shelf (n), extending entirely across the receiver on one side, but having in it openings through which the pendulum, dummy, and lever (o) hang. This shelf carries on one side a plate on which the dummy pendulum is supported (not shown), and on the other the plate (m) resting on the shelf on three points and screwed to it. This plate has embedded in it the agate planes on which the pendulum swings, and holds the pivots for the lever used in lowering and raising it. The plate (m) has screwed to its face an adjustable piece (g) holding the fixed mirror, which is so adjusted that the images of the slit, as seen in the observing telescope, reflected from this mirror, and from that on the pendulum when hanging freely at rest, will appear to be in the same horizontal line, and slightly overlap each other.

The horizontality of the agate planes is tested by means of a sensitive level mounted over a knife edge, similar to those of the pendulums, and having a suspended weight to bring the center of gravity below the planes. This is placed and reversed on the planes in the same manner as a pendulum. The adjustment is made with the three heavy foot screws on which the receiver stands, two levels mounted on the outside being used in bringing the receiver to an approximately correct position. These outside levels are also read after the final adjustment has been made, and any change in level during a day's observations is detected and corrected through them.

The pendulum is set in motion or stopped by the arm (r), covered with leather at the point of contact, which is worked from the outside of the receiver by the handle shown in illustration No. 23. Adjustable screws limit the motion of this handle in each direction, so that it may be set for any desired amplitude of oscillation, and the same amplitude used for succeeding swings.

A millimetre scale for reading the arc of oscillation is fastened in the bottom of the receiver immediately under the point of the pendulum,

and is graduated from zero in the center. A microscope (not shown) carrying a mirror to throw light on scale and point is mounted opposite on the outside of the receiver. A white line on the point of the pendulum is bisected by a vertical thread in the microscope, and the scale read where the thread intersects it, the extreme arc on each side of the vertical being read in this way. The pointing of the microscope is controlled by a quick-motion screw.

A manometer is placed on one side of the receiver, one end open to the air and the other connected with the interior (No. 23). The scale reads in millimetres from zero in the center. A graduated pipette is provided for filling the manometer with mercury. The manometer is removed for shipment. Two stop cocks (No. 24) on the side of the receiver afford a means of connecting with the air pump through a rubber tube. Three windows are provided through which to observe the mirrors, the arc scale, and the dummy thermometer, respectively. The interior of the chamber is covered with chamois skin to protect the pendulum from injury should it accidentally touch the walls in handling. An aligning device fits on the top of the receiver. By bringing the telescope into range with two crosses on this, it may be quickly placed in the correct position for observing, so that the image of the slit as reflected from the mirrors will be in the field. The stuffing boxes for the lifting screw and starting lever, as well as the joints of the windows, are constructed in such a manner as to make the receiver practically air-tight.

Pendulums.—Three pendulums constitute a set, the advantage of this number being that if discrepancies appear in the results the one at fault may be detected. Each is designated by a letter showing the set to which it belongs and its individual number; the three used in the observations included in this report being A1, A2, and A3. The pendulums are made of an alloy of aluminum 10 per cent and copper 90 per cent, a composition which experiment proved to have a very high resistance to corrosion; they are highly polished but not lacquered. Each weighs approximately 1 200 grammes*, and is about 248 millimetres in length from the center of the bob to the knife edge. The lengths of A1, A2, and A3 differ slightly, however, their coincidence periods at Washington being at ordinary temperatures about 4·8 minutes, 5·5 minutes, and 6·2 minutes (sidereal), respectively.

* The A pendulums were weighed twice in 1891, and the following results are given by the Office of Standard Weights and Measures:

	March 14.	October 30.
	Grammes.	*Grammes.*
Pendulum A1.	1213·091	1213·096
Pendulum A2.	1197·537	1197·548
Pendulum A3.	1196·373	1196·376

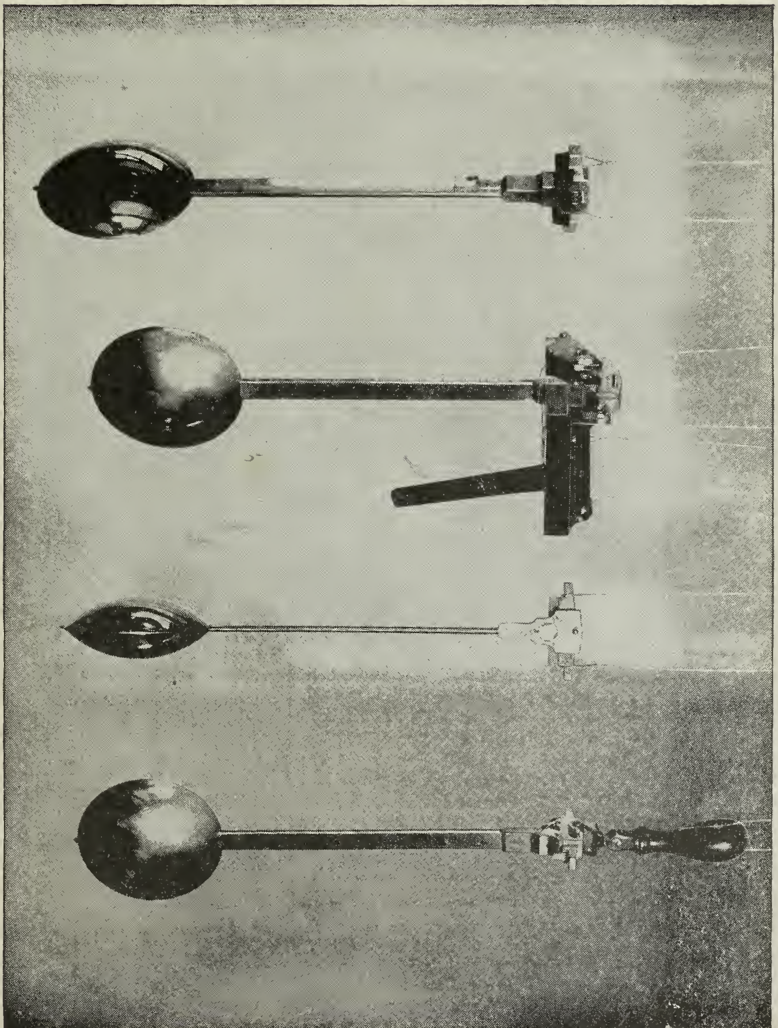


FIG. 1. FIG. 2. FIG. 3. FIG. 4.

THREE HALF-SECOND PENDULUMS AND DUMMY PENDULUM.

Determinations of gravity with the new half-second pendulums—Continued.

The stem and bob are designed so as to offer little resistance to the air when in motion. The bob is solid, and is 9 centimetres in diameter and 4·5 centimetres thick at the center, its faces being spherical surfaces, as shown in No. 25. The stem of the pendulum is rectangular in section, 4 by 14 millimetres, with rounded edges, and is rigidly fastened to the head and the bob.

The knife edge is a continuous piece of agate passing through the head of the pendulum and firmly secured to it, and the edge proper is formed by the meeting of carefully ground faces at an angle of about 110°. It is 43 millimetres in length, the bearing on the agate planes on which the pendulum swings being about 12 millimetres at each end. The two pieces of agate forming these planes are rigidly embedded in a heavy brass plate (m) already mentioned, and ground to a single true surface after they are in position.

A small circular mirror is set in each side of the pendulum head. A careful adjustment was made of these mirrors, so that from any of the pendulums with either face front the image of the slit will be reflected into the same portion of the field of the observing telescope when the latter is properly placed.

The pendulum is carried from the box in which it is kept to the receiver by a double-jointed handle (illustration No. 25, Fig. 4), which has rubber-lined hooks fitting under pivots on either side of the head. It is, therefore, never necessary for the hand to come in contact with the pendulum. When placed in the receiver the pendulum is first suspended upon two pivots carried on the end of the lever l, which pivots fit into corresponding sockets in portions of the head projecting at either end over and beyond the knife edge. This lever is moved by a screw (q) on the outside of the receiver, so that the pendulum may be gradually lowered until it hangs freely upon the agate planes, or may be raised therefrom, the object being to avoid injury to knife edge or plane, which would be likely to result from suspending the pendulum directly by hand. A spring holds the lever against the end of the screw, and stops limit its motion, and a device (not shown) indicates on the outside of the receiver whether the pendulum is hanging on the planes or on the lever.

The temperature of the swinging pendulum is ascertained by means of a dummy, similar to the others in material and dimensions, save that it has no mirrors, and is supported upon two hard-rubber knife edges parallel to the plane of the bob, and has a thermometer fastened to one side of its stem. The bulb of the thermometer, bent back for the purpose, is packed with alloy filings into a small metallic box, and this box is pressed with tinfoil into a slot cut in the stem of the dummy immediately above the bob, a very close metallic contact between the bulb and the surrounding metal being thus attained. The dummy is suspended near the pendulum and is prevented from oscillating by the

nature of its support, and by a fork projecting from one side of the receiver and holding it firmly near the bob.

Flash apparatus.—A light metal box is mounted on a stand having both vertical and azimuthal movements and clamps, and carries above it an ordinary observing telescope, which may be focused for objects as near as four feet. This apparatus is shown in Nos. 23 and 24, and with one side of the box removed in illustration No. 26 (Fig. 4). This box contains an electro-magnet (*a*), whose coils are connected with the chronometer circuit through the binding posts (*f*), and whose armature carries a long arm (*d*), projecting through an opening in the end of the box. This arm moves two shutters, *t* and *v* (Figs. 6 and 7), and by an ingenious device a flash of light is emitted from the box when the circuit is broken, but not when it is closed. This arrangement is shown in Fig. 6, a vertical section of the front of the box and shutters, showing position just after the circuit has been broken and the arm is rising, and in Fig. 7 showing position when circuit has closed and arm is descending. The front of the box has an opening containing a piece of finely ground glass for defusing the light. In front of this are fastened two pieces of metal *z*, leaving a narrow horizontal slit between them. Behind the ground glass move the two shutters, *t* and *v*, in suitable guides, and having horizontal slits in them of the same size as that between the pieces *z*. The arm *d* passes through the upper end of these two shutters; *t* has no play on the arm, but moves directly with it; the opening in *v*, however, is somewhat longer than the thickness of the arm, so that it does not move until the arm is near the middle of its stroke. A stop prevents the slit in *v* from descending below that in *z*, and a friction spring holds *v* so that it moves only with the arm. When the circuit is closed the arm *d* is down and the slit *t* is below the line of slits *v* and *z*. As soon as the circuit is broken the spring *h* causes the arm to rise and the slit *t* passes the line of the slits *v* and *z*, emitting a flash (position shown in Fig. 6). Before the end of its stroke the arm also lifts the shutter *v* so that its slit is no longer in line with *z*. When the circuit is again closed the arm *d* is pulled down, but the slit in *t* is opposite that in *z* when *v* just commences to move (position shown in Fig. 7), so that the three slits are not in line and no flash is emitted. It is thus seen that the three slits are only in line immediately after the breaking of the circuit, and only one flash is given out each second. The light for the flash is furnished by a small oil lamp attached to one side of the box, the light from which is concentrated by a lens on to the slit after being reflected by a mirror in the interior of the box set at an angle of 45°.

The apparatus is also arranged to use the spark of a Ruhmkorff coil instead of the flash from the slit. The chronometer is placed in the circuit of the electro-magnet as before, but this now acts as a relay, a platinum tip on the end of the arm *d* breaking and closing the primary circuit of a Ruhmkorff coil as it rises and falls, connections being

ig. 6

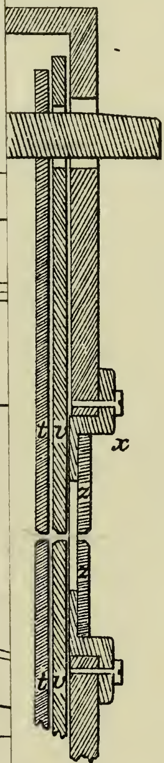
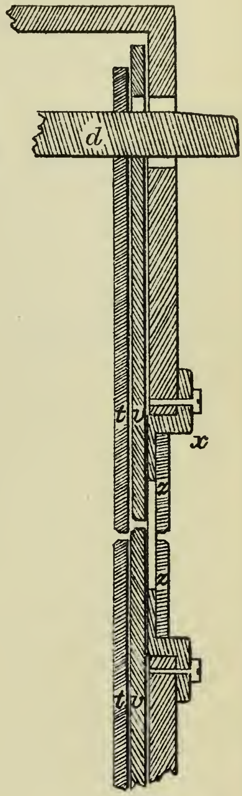


Fig. 7



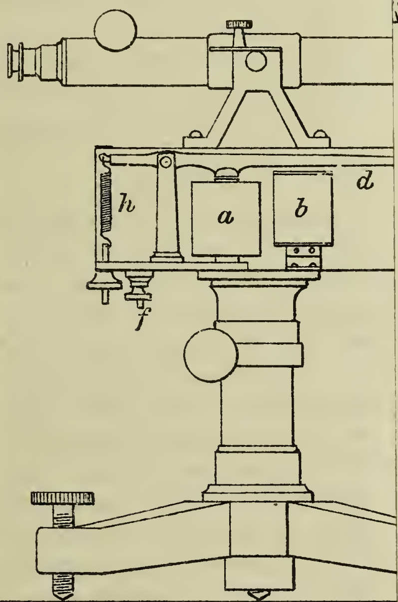
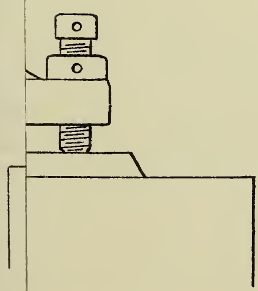


Fig. 4



Side elev shutters.

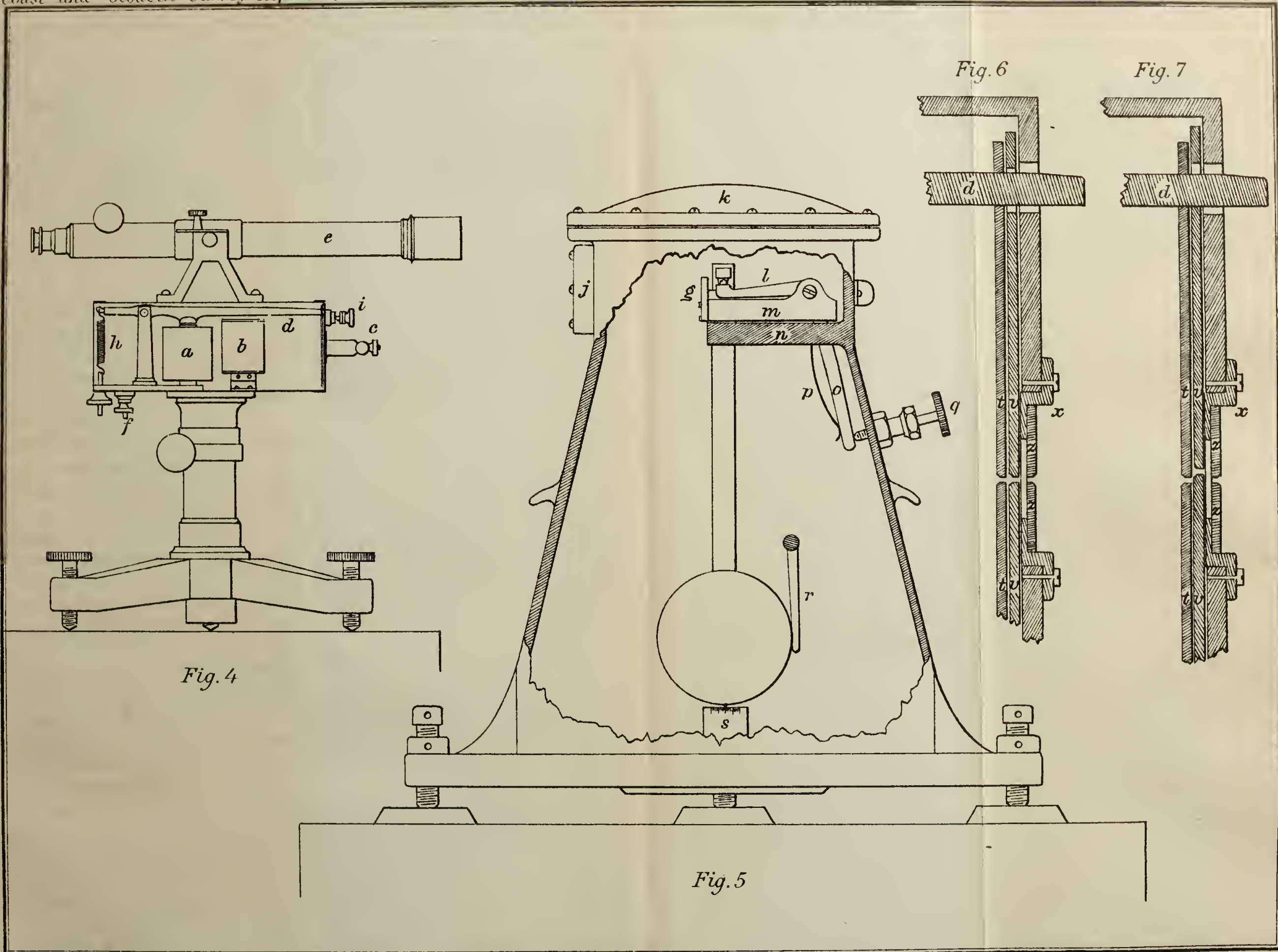


Fig. 4

Fig. 5

Side elevation of receiver and flash apparatus and section through shutters.

Determinations of gravity with the new half-second pendulums—Continued.

made through the binding posts *i*. Platinum-tipped screws on the posts *c* are the terminals of the secondary coil, between which a spark is thrown at each break of the chronometer.

The entire apparatus, except barometers and chronometers, is packed in two boxes, one 38 by 19 by 16½ inches in size, the other 21½ by 21 by 17 inches, weighing together about 360 pounds, the whole being quite convenient for transportation. The pendulums and dummy are packed in a small box by themselves, lined with chamois skin, and fitted so as to relieve them of any strain. The thermometer is removed from the dummy in packing so as to avoid any danger through breakage of the thermometer and destruction of the pendulums by amalgamation.

USE OF THE APPARATUS.

One of the principal advantages of this apparatus is the ease with which it may be used, and the few and inexpensive preparations necessary for its installation. The latter will depend in some degree upon the importance of the station to be occupied, or the degree of accuracy intended to be reached in the results. For the best work, a well-founded brick or stone pier upon which the vibration chamber may rest is essential. The flash apparatus, which is distant from this about two metres, may be placed upon any convenient support, stability not being essential. If the apparatus can be placed in a room of nearly constant temperature the results will be more uniform, but if sufficient time is allowed before swinging for the pendulum to come to the temperature of its chamber, as represented by the thermometer in the "dummy," this is not essential. The correction for temperature may be so well known that results obtained at temperatures differing widely will be in close accord when this correction is applied. The work may be done in a very small room, a ground space of not more than two metres square being required. The room should be somewhat dark in order that the flash may be easily seen in the field of the telescope.

In the Alaska work it was necessary to resort to the most primitive method for mounting and protecting the apparatus, there being no facilities for a more perfect installation and no time for making it.

A small tent, barely large enough to afford room for the observer after the apparatus was mounted, was used for protection against wind and rain, the latter occurring almost daily. The pendulum chamber was usually mounted on a triangular pyramidal support of wood, made of three stout legs forming the edges of the truncated pyramid, securely joined together by pieces of planking on the faces and strong cross braces within. The height of the support was about 40 centimetres, and the three levelling screws of the chamber rested on the ends of the three corner posts. Sometimes this support was placed upon a bare, exposed rock, but generally it rested upon the ends of three pieces of heavy scantling, 60 to 80 centimetres long, driven into

the ground so that the ends were flush with the surface. In one or two instances, especially at Sitka, the chamber rested directly upon the surface of exposed rock, the wooden support not being used.

This support was thought to be so rigid that it would not flex or vibrate when the pendulum was in motion, but before the Alaskan series was completed it began to be suspected, and it was, therefore, brought to San Francisco, where a series of comparisons was made and a correction for flexure determined, which was applied in all cases where the wooden stand had been used.

The use of this stand made it possible to establish and disestablish a station in a very short time. On several occasions a single day was all that was available, and even in so short a time it is believed that a fairly correct value of the force of gravity was obtained. At Yakutat Bay the outfit was landed in the forenoon, with some difficulty, through the surf. A station was established, two swings of each pendulum, six in all, were made, the instruments packed, taken out to the ship which lay at anchor some distance away and safely put on board ready for leaving in the evening.

After placing the support, or selecting the rock or pier when either is available, the chamber is lifted out of its packing box and put in position. It is then leveled, and the relation between the agate planes and the exterior level is determined by means of the small pendulum level already described. The "dummy" is then put in place and the first pendulum to be swung is placed in the chamber on the "lifter," that it may come to the normal temperature as soon as possible. The thermometer belonging to the dummy is not carried with it, however, and must always be put in its proper place before the dummy is put in the chamber.

The cap is placed in position on the chamber, the surfaces of contact having been cleaned and a very little tallow rubbed upon them. By moving the cap from side to side, under considerable pressure from the hands, a good joint is generally produced without difficulty. The manometer, which is packed separately, is put in place and the mercury poured in it. The air-pump is attached and the pressure in the chamber reduced to about 50 centimetres, the desired reading of the manometer being ascertained by referring the barometer reading and the temperature within the chamber to a table prepared for this purpose.

The flash apparatus is next put in position. This may have been done approximately by means of the index described above, but after a little experience this will be discarded and the telescope will be quickly placed by reference to the reflected image of the slit from the fixed and movable mirrors in the chamber. When this adjustment has been completed, the chronometer, placed conveniently so that its face can be easily seen, is connected electrically with the flash magnet, and if the images of the illuminated slit are sharp and properly related the apparatus is in readiness for work.

Determinations of gravity with the new half-second pendulums—Continued.

In beginning an observation the pendulum is lowered into its place on the agate planes, is carefully drawn aside by the lever arranged for that purpose, and allowed to rest for a few moments. As nearly as possible in coincidence with a beat of the chronometer the external arm of this lever is quickly pushed back to its place, thus setting the pendulum free to vibrate through the desired arc. If the starting is properly made there will be plenty of time for the observer to take his place at the telescope before the first coincidence occurs. As soon as this is observed the arc of vibration is read, the temperature and barometric pressure noted, and the height of the mercury in the two arms of the manometer. These observations can usually be made and recorded before the time arrives for the second coincidence, the interval being about four minutes.

It is customary to observe the first four and the last three of a set of twelve coincidences, and at the middle of the whole time the temperature, barometric pressure, manometer, and arc, may be observed and recorded

At the end of the set these readings are again made and the pendulum may be reversed, or, if time permits, another set in its same position may be made. In all cases the same number of sets, direct and reverse, should be made with each of the three pendulums.

The apparatus appears to resist the effects of rough handling very successfully. A comparison of the vibration periods of the pendulums, as determined in Washington in March, 1891, and again in October of the same year, after the Alaska campaign, involving a journey of nearly 15 000 miles, proves that their constancy may be depended upon.

GRAVITY EXPERIMENTS IN 1891.

A visit of inspection to the Pacific Coast and Alaska having been planned for the spring and summer of 1891, it seemed extremely desirable to take advantage of it for the purpose of testing the new apparatus in the field, and especially as it would be possible in this way to obtain fairly accurate measurements of the force of gravity at high latitudes in a somewhat inaccessible part of the world. The finishing of the first set of pendulums, with their accompanying apparatus, was somewhat hurried, as was also that of the second set, which, it was determined, should be carried by Mr. Preston to the Hawaiian Islands, where he was to be located during the succeeding year for the purpose of making latitude observations in co-operation with the observer sent by the International Geodetic Association. No essential feature was overlooked, however, and the first swinging of the pendulums, away from Washington, occurred in April at San Francisco, the station occupied being the small observatory of the U. S. Coast and Geodetic Survey in Lafayette Park, in that city. This point had been occupied as a gravitation station by previous survey parties, the Kater pendulums having been swung

here by Mr. Edwin Smith, and the Peirce pendulums by Mr. Preston. It therefore furnished a check on the invariability of the pendulums. Much valuable assistance was rendered at San Francisco by Assistant George Davidson, and by Subassistant Fremont Morse, who accompanied the writer to Alaska, sharing with him the labor and responsibility of all the work on the Pacific Coast.

After the work at San Francisco was completed, the apparatus was shipped to Port Townsend, where it was taken on board the Coast Survey steamer *Patterson*, Lieut. Commander H. B. Mansfield, U. S. Navy, Assistant U. S. Coast and Geodetic Survey, in command, and on the morning of April 23 the party sailed for Alaska.

In all of the gravity work undertaken during the journey every facility was afforded by Capt. Mansfield, and much valuable assistance was received from the officers of the *Patterson*, who evinced a real interest in the work and a willingness to do whatever could be done to aid in its success. Especial mention should be made of the executive officer, Lieut. Dorn, who looked after the camp outfit and under whose directions the pendulum equipment was always put ashore or brought aboard ship, not only with promptness but, what was of greater importance, without the slightest injury to the apparatus during the entire campaign. Particularly valuable were the services of Ensign Poundstone, who made such time observations as were possible, often under the most unfavorable and disagreeable conditions, due to the almost continuous rains, which sometimes prevented the seeing of a star for many days in succession.

The gravity work done in Alaska can only be considered as secondary in its character. It was subordinated to the general inspection of the coast and the survey of the same in which the *Patterson* had been engaged for several years, and the time given to it was necessarily short. In no case, however, are there less than six independent swings, each of the three pendulums having been swung twice, and it is believed that an examination of the results will show that they have sufficient value to justify the labor bestowed upon their production.

After leaving Alaska, the first station occupied was in Seattle. This point was reached on June 21, and on the evening of the 22d the swinging was commenced. The pendulums were swung in a room in the basement of the high school building, for which permission was kindly granted by Mr. Barnard, superintendent of the public schools of Seattle. The swinging was continued through the night as well as the day, the observations after midnight being undertaken by Mr. Morse. Valuable assistance was here rendered by Assistant Pratt, who was stationed at Seattle at that time. Time signals from the Mare Island Navy-Yard Observatory were furnished through the courtesy of Mr. Overbeck, manager of the Western Union Telegraph office. The attempt was made to secure signals from the Lick Observatory, the director, Prof. Holden, having kindly offered to furnish

Determinations of gravity with the new half-second pendulums—Continued.

them, but this was prevented by a difficulty in the connection between Mount Hamilton and San Francisco.

The Lick Observatory, on Mount Hamilton, was reached on the afternoon of July 2, and by the evening of that day the apparatus was ready for use. Through the courtesy of the director, Prof. Edward S. Holden, this station had been occupied by Mr. Preston with the Peirce pendulums in 1887, and by the same courtesy it was occupied on this occasion. An admirable room for swinging was provided and every required facility was offered. Special observations for time were made by Mr. Barnard, and nothing was left undone by the director and his staff that could in any way tend to insure the success of the observations or the comfort of the observers.

On the 8th of July the pendulums were again at the observatory in San Francisco, and a series of swings were commenced, extending through several days and including a comparison of swings on the wooden stand used in the Alaska work with those upon the brick pier of the observatory. The work was done for the most part by Mr. Morse.

On the afternoon of the 16th of July the apparatus was placed on board the Fish Commission steamer *Albatross*, which carried Dr. C. H. Merriam, of the Department of Agriculture, and the writer as representatives of the United States in the Joint Commission agreed upon by the United States and Great Britain for the purpose of studying and reporting upon the condition of seal life upon the Pribilof Islands. Advantage was taken while on the islands of a single day in which bad weather interrupted other work, but did not prevent the installation of the pendulum apparatus and the swinging of each of the three pendulums two hours each. A small tent was used as a shelter and the chamber was mounted on a large block of wood, which in turn rested directly upon the surface of the ground. It was a very solid and stable mounting. The conditions at this station in other respects were not favorable, especially as regards time. The dense clouds and fog which almost constantly hang over these islands made time observations impossible, but in this matter valuable assistance was rendered by the executive officer of the *Albatross*, Lieut. Carlos G. Calkins, who made comparisons of the pendulum chronometer with the ship's chronometers during the passage and while the ship was lying at the Pribilof Islands, coming ashore with a "hack" chronometer for this purpose while the observations were in progress.

In October the pendulums reached Washington and were again vibrated at the Smithsonian Institution, about half of the observations being made by Mr. E. G. Fischer. The results agreed in an extremely satisfactory manner with those obtained before the journey to the west.

In November they were swung in Hoboken, in the room in the basement of the Stevens Institute, which, through the courtesy of the

president, Dr. Henry Morton, has been at the service of the Survey for several years for this purpose. The work was greatly facilitated by the kindness and co-operation of Prof. Mayer and Dr. Geyer, in charge of the departments of physics and electricity in the institute.

In Hoboken, as well as in all of the work in Washington, special time-signals were received from the Naval Observatory. These were sent through the kindness of the superintendent, Capt. F. V. McNair, and to insure their accuracy special observations were made by Prof. Brown.

Time.—Several different chronometers were used in the series, and their rates were determined by various methods, varying greatly in excellence. The chronometers themselves differed much in quality. It was unfortunate that in the Alaska work, when it was necessary to rely almost entirely on the constancy of rate of the chronometer, only an inferior instrument was available. Negus No. 1824, an excellent chronometer, was used at Washington and at San Francisco, and it was intended to use it throughout the Alaska work. After it had reached the Patterson it was found to have suffered a serious injury, resulting doubtless from an accident which occurred just after the San Francisco swings were finished. It was necessary, therefore, to make use of a mean time break-circuit, No. 2490, which had, fortunately, been carried along to provide against accident to the better instrument. Unfortunately this chronometer was unsteady and unreliable as to its rate, and the results of the Alaska tour are less satisfactory than they would have been had it not been for this accident.

Unquestionably the element of time is by far the weakest in these determinations, even under the most favorable conditions. The coincidence of the fixed and movable flash can always be determined within one second. An error of one second in the time of ten coincidence intervals will affect the period of the pendulum by about one part in two millions. It will thus be seen that, if there was no other uncertainty, a swing for a single hour would leave nothing to be desired. Variations due to the effects of temperature are well under control, and the corrections for varying density of the air in the chamber may be made as small as can be desired. The varying rate of the clock or chronometer is the one thing which is imperfectly understood and controlled. The pendulums themselves are far more uniform and constant in their vibratory periods than the balance wheel of the chronometer; are much better time pieces in fact than the standards with which they are compared. It is well known that a clock may have a tolerably uniform *daily* rate, while its *hourly* rate may be quite irregular. Besides, the daily rate may be checked quite accurately by means of astronomical observations. It is, therefore, essential that whenever an accurate result is desired the swings should be continuous through the twenty-four hours.

The irregularities of rate may, to some extent, be estimated by

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frequent intercomparisons of several chronometers or clocks. This is greatly facilitated by the method employed, as is shown in another part of this paper in connection with the proper use of the invariable pendulum as a time standard. Indeed it is quite possible to use two or three chronometers in the operation, switching one after the other into the circuit of the flash apparatus, observing the coincidences due to each, and thus determining the period of the pendulum in reference to each of the several timepieces. For differential gravity work it is possible, however, to avoid the use of timepieces altogether, and it is likely that this will eventually be done whenever practicable; that is, whenever telegraphic connection between two stations can be obtained. The methods to be adopted will be given in some detail in another part of this paper. A brief description of the method of determining rates at the various stations here under consideration is given below:

RATES OF CHRONOMETERS.

Washington, D. C., March, 1891.—Chronometer Negus 1824 (sidereal) was used in the pendulum observations, and its rate was obtained by a comparison with the Naval Observatory clock at noon each day, telegraphic signals being received and recorded on chronograph. The corrections to the noon signals as derived from time observations made each evening were communicated by Capt. F. V. McNair, Superintendent of the Naval Observatory. Nearly all of the pendulum observations were made between the noon signals of March 17 and 18, and the rate for this interval was used.

San Francisco, Cal., April, 1891.—Chronometer Negus 1824 (sidereal) was used in pendulum observations. Time observations were made at the Lafayette Park Observatory on the evenings of April 9, 10, 11, and 14, by Fremont Morse, subassistant, using transit No. 3 and chronometer 3479 (sidereal). Chronometers 1824 and 3479 were compared through mean time chronometer 5038 at the time of observations each evening, and also several times each day, before, after, and during the pendulum observations. The rate for each swing was arrived at by taking a mean between the rate for a day as derived from the evening comparisons, and the rate as calculated from the daily comparisons, usually covering an interval of time including two or three swings.

Port Simpson, British Columbia.—Chronometer 2490 (mean time) was used in pendulum observations. On April 22, 1891, at Port Townsend, Wash., one of the ship's chronometers, H (sidereal) was taken ashore and compared with time signals from the Naval Observatory, Mare Island, Cal. H was also compared, before and after taking ashore, with the three mean time chronometers C, B, and G, and thus the error of these three chronometers on Greenwich mean time arrived at. At Port Simpson, on April 29, time observations were made by H. C. Poundstone, Ensign, U. S. Navy, using H and Meridian Instrument No. 7, and after the observations H was compared with C, B, and G, and their errors on Greenwich mean time computed, and also their rates from the 22d to the 29th. 2490 was compared with C, B, and G, through H, before and after the pendulum observations on the 29th, and its rate calculated from the rates of each of these, and the mean of these three values adopted as the rate of 2490 at Port Simpson.

Juneau, Alaska.—Chronometer 2490 (mean time) was used in pendulum observations. On May 9 time observations were made by Ensign Poundstone as at Port Simpson, and the rates of C, B, and G from April 29 to May 9 computed. No. 2490 was compared with C, B, and G through H on May 11 and 12, before and after the pendulum observations each day, and the mean of the values derived from the three chronometers adopted as the rate for each day.

Pyramid Harbor, Alaska.—Chronometer 2490 (mean time) was used in pendulum observations. Time observations were made on May 17 and 18 by Ensign Poundstone at Chilkat, about 3 miles from Pyramid Harbor, using Meridian Instrument No. 7 and chronometer H as before. On May 16 the chronometers C, B, and G were considerably shaken up by a passage across the bay in a small boat during a strong wind. The rates of C, B, and G, derived from comparison with H at the time of observations of the 17th and 18th, are therefore not used, it being considered that they had not settled to uniform conditions of running, but rates are computed for the interval from May 9 (time observations at Juneau) to May 17. The rate of 2490 is obtained from comparison with C, B, and G, made through H, on May 15 and 19, before and after the pendulum observations. The rate at this station must be considered as somewhat doubtful.

Yakutat Bay and Sitka.—Chronometer 2490 (mean time) was used in pendulum observations. Time observations were made at Sitka by Ensign Poundstone on May 28 as before. Chronometer H, used in observing time, was afterwards compared with C, B, and G, and the rates of C, B, and G deduced from May 18 (time observations at Chilkat) to May 28. 2490 was compared with C, B, and G through H before and after each day's pendulum observations at Yakutat Bay (May 22) and Sitka (May 26, 27, and 28), and a rate obtained for 2 490 based on the rates of C, B, and G.

Wrangell and Burroughs Bay.—Chronometer 2490 (mean time) was used in pendulum observations. The preceding rates of C, B, and G (based on time observations of May 18 and 28) were used, no further time determinations being made; 2490 was compared with C, B, and G through H, before and after each day's pendulum observations, at Wrangell on June 1 and 2, and at Burroughs Bay on June 4 and 6, and a rate obtained for 2490 based on the rates of C, B, and G.

Seattle, Wash.—Chronometer 2490 (mean time) was used in pendulum observations. Noon signals were received by telegraph on June 22, 24, 25, and 26, from the Naval Observatory, Mare Island, Cal., and recorded in the time of chronometer 387 (sidereal). The corrections to the time signals were communicated by Charles F. Pond, Lieutenant, U. S. Navy; 387 was compared with 2490 each day before and after receiving the noon signals, and also before, during, and after the pendulum observations. The rate of 2490 was calculated between each two noon signals, and also from the comparisons made before and after the pendulum observations, and the mean of the two rates thus obtained adopted for each swing according to its epoch.

Mount Hamilton, Cal.—Negus 1720 (sidereal) was used in pendulum observations. The errors of 1720 were carefully determined at the Lick Observatory by comparison with the standard clocks of the Observatory at frequent intervals, the corrections to these clocks being determined by frequent observations during the entire time of the swings. The rates of 1720 between these comparisons were then calculated and plotted for the middle times of the intervals, a curve drawn, and the rate for each pendulum swing read from this curve according to the middle epoch of the swing.

San Francisco, Cal., July, 1891.—Chronometer 3479 (sidereal) was used in pendulum observations. Time observations were made by Fremont Morse, subassistant, at Lafayette Park Observatory, on July 7, 10, 11, and 14, using transit No. 3 and Kessel's clock No. 1449; 3479 was compared with Kessel's clock on the chronograph at the time of observations each evening, and also at frequent intervals during the pendulum observations. From the former comparisons a rate for each day was deduced, and from the latter a rate for each interval between comparisons. A mean of these rates was adopted for each swing according to its epoch.

St. Paul Island, Bering Sea.—Chronometer 2490 (mean time) was used in pendulum observations. The errors of 2490 were derived from comparisons with the ship's chronometers. There is considerable uncertainty as to the rate at this station.

Washington, D. C., October, 1891.—Chronometer Negus 1589 (sidereal) was used in

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pendulum observations. This chronometer was compared four times a day with the E. T. clock (sidereal) at the U S. Naval Observatory, by means of telegraphic signals received on chronograph. The errors of the Naval Observatory clock were communicated by S. J. Brown, professor, U. S. Navy, as derived from time observations made by him. The rate of 1589 was calculated for each interval between comparisons, and plotted, and the rate for each swing taken from this diagram.

Hoboken, N. J.—Chronometer Negus 1824 (sidereal) was used in pendulum observations. Telegraphic time signals were received from the Naval Observatory at Washington three times a day, and the rate for each swing arrived at in same manner as at last station. The errors of the Naval Observatory clock were communicated by Prof. Brown as before, based on his own time observations, and on comparisons with other standard clocks.

REDUCTIONS.

The periodic time, as ascertained from the coincidence period, must be corrected for arc, temperature, pressure, and rate, and, in the case of some of the Alaska stations, for flexure of wooden stand. It is reduced to that of an infinitely small arc. The standard temperature is 15° C., and the temperature coefficient was ascertained by swinging the pendulums under conditions differing considerably in that respect, and the result checked by a determination of the coefficient of expansion of the metal. The standard density of air in the chamber was that of 50 centimetres pressure at 0° C., and this standard was generally closely realized in each experiment. The corrections for rate have already been referred to. A detailed explanation of the method of computing and applying these several corrections is given by Mr. Putnam, as follows:

EXPLANATION OF TABLES, AND METHODS OF REDUCTION.

Position.—D (direct) indicates that the pendulum is swung with the face marked with date towards the observer. R (reversed) indicates date away from observer.

Observer.—The observers are designated as follows:

M = T. C. Mendenhall.
Mo = Fremont Morse.
P = E. D. Preston.
S = Edwin Smith.
F = E. G. Fischer.
Pm = G. R. Putnam.

Ten coincidence intervals.—In this column is given the time in seconds of ten coincidence intervals for each swing. The method of observation finally adopted was to note the time of the first, second, third, fourth, tenth, eleventh, and twelfth coincidences, the first, third, and eleventh being "down" coincidences (the reflected image from the pendulum appearing to move downward across the field of the telescope), and the second, fourth, tenth, and twelfth "up" coincidences (image apparently moving up). The time of ten coincidence intervals is then obtained by subtracting the first from the eleventh, and the second from the twelfth, and taking the mean of these two results. At Washington, in March, 1891, however, the twelfth coincidence was not observed, and the time is obtained by subtracting the first from the eleventh coincidence.

Semi-arc.—The initial and final semi-arcs of oscillation for each swing are given, as read in millimetres on the scale near the point of the pendulum, the mean of

readings on each side of the vertical being used. (The pendulum at rest hangs at or near the zero on the scale). The distance from this scale to the plane on which the pendulum swings is 297 millimetres. Scale readings, therefore, indicate angles with the vertical as follows:

	°	′	″
3·0 millimetres =	0	34	44
3·5 =	0	40	31
4·0 =	0	46	18
4·5 =	0	52	05
5·0 =	0	57	52

Before the observations at Hoboken were made, a small telescope was mounted on the side of the receiver, so that the arc readings could be made with greater accuracy.

Temperature.—The thermometer (No. 6594) on the dummy was read at the beginning and end and usually in the middle of each swing. The mean of these readings, corrected for error of thermometer, is given. The corrections to thermometer 6594, as determined by the Office of Standard Weights and Measures, January, 1891, are:

°	°
At 0 C.	+0·10
5	+0·10
10	0·00
15	−0·03
20	0·00
25	−0·03
30	−0·04
35	−0·08

Pressure.—The barometer and manometer were read at the beginning and end, and usually in the middle of each swing, and the means of these readings are given. To the difference between the barometer and manometer is then applied the correction for reducing the barometrical column to the freezing point, and this pressure is then divided by $1+\alpha t$, where t is the mean temperature in degrees centigrade, and α is ·00367, the coefficient of expansion of air for one degree centigrade. The result $\frac{Pr}{1+\alpha t}$ is the corresponding pressure at a uniform temperature, 0° C.

Uncorrected period.—When a sidereal chronometer is used, these pendulums make one less oscillation than twice the number of seconds between two coincidences; therefore, $P=\frac{s}{2s-n,}$ where P is the period in seconds, s is the number of seconds between first and last coincidences, and n is the number of coincidences minus one, or the number of coincidence intervals. When n is ten, $P=\cdot 5+\frac{1}{\cdot 4s-2.}$ When a mean time chronometer is used the pendulums gain on the chronometer, and $P=\frac{s}{2s+n,}$ and where n is ten, $P=\cdot 5-\frac{1}{4s+2.}$ Mean time periods are reduced to sidereal time by multiplying by 1·00273791, or more simply by adding differences which are first tabulated for various values of P.

Arc correction.—This correction, to reduce the time of oscillation to what it would be were the pendulum swinging in an infinitely small arc, was computed by means of Borda's formula—

$$b=\frac{Mn}{32}\frac{\sin(\varphi+\varphi')\sin(\varphi-\varphi')}{\log\sin\varphi-\log\sin\varphi'}$$

where M is the modulus of the common logarithmic system, n is the number of oscillations actually made, φ is the initial semi-arc, φ' is the final semi-arc, and b is the

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quantity to be added to n oscillations in order to obtain the number that would have been made in the same interval had the arc been infinitely small.

Transforming this expression into a correction to the period it becomes, with a sufficient degree of accuracy where the arc is small—

$$A = \frac{P\,M}{32}\,\frac{\sin(\varphi + \varphi')\sin(\varphi - \varphi')}{\log\sin\varphi - \log\sin\varphi'}$$

where P is the period of the pendulum in seconds, and A is the amount to be subtracted from period to reduce to infinitely small arc.

Temperature correction.—Each period is corrected for the difference between the mean temperature of the swing and 15° C., adopted as a standard. The temperature and pressure coefficients of the pendulums were determined by swinging them at widely different temperatures and pressures at the Coast and Geodetic Survey Office before they were used at any of the gravity stations. These observations are tabulated below:

Observations for determination of temperature and pressure coefficients of A_1, A_2, A_3, at Coast and Geodetic Survey Office, Washington.

[Observers: E. D. Preston, G. R. Putnam, All swings made with pendulums in position "direct," and at uniform initial arc of oscillation.]

Pendulum.	No. swing.	Date (1891).	Ten coincidence intervals.	Mean temperature.	Mean pressure.	$\frac{Pr}{1+at}$.	Period uncorrected.	Correction for rate.	Period corrected for rate.
A_3	1	Mar. 9	3 689·0	8·05	758·0	736·3	·5006786	+ 35	·5006821
	2	9	3 699·0	7·90	756·6	735·3	6768	+ 35	6803
	3	9	3 803·0	7·80	498·4	484·5	6582	+ 35	6617
	4	9	3 804·0	7·95	500·1	485·9	6581	+ 35	6616
A_2	5	9	3 302·0	9·38	503·0	486·3	7583	+ 35	·5007618
	6	9	3 307·5	9·25	500·6	484·2	7570	+ 35	7605
	7	9	3 224·5	9·18	759·8	735·0	7765	+ 35	7800
	8	9	3 231·5	8·70	761·4	737·9	7748	+ 35	7783
A_1	9	10	2 832·5	6·50	769·2	751·3	8842	+ 38	·5008880
	10	10	2 833·0	6·55	769·5	751·5	8840	+ 38	8878
	11	10	2 893·1	6·60	506·4	494·4	8656	+ 38	8694
	12	10	2 891·5	6·70	510·9	498·6	8661	+ 38	8699
A_1	13	10	2 736·0	20·90	509·6	473·4	9154	+ 38	·5009192
	14	10	2 728·0	21·65	513·3	475·4	9181	+ 38	9219
	15	10	2 671·5	22·55	770·4	711·6	9375	+ 38	9413
	16	10	2 666·5	23·02	770·5	710·5	9393	+ 38	9431
A_2	17	11	2 959·0	26·60	771·5	702·9	8463	+ 38	·5008501
	18	11	2 953·0	27·00	771·2	701·7	8480	+ 38	8518
	19	11	3 010·5	27·52	505·1	458·8	8318	+ 38	8356
	20	11	3 006·0	27·98	508·8	461·5	8330	+ 38	8368
A_3	21	11	3 300·5	28·70	769·6	696·3	7586	+ 38	·5007624
	22	11	3 291·0	29·10	769·1	694·9	7608	+ 38	7646
	23	11	3 339·5	30·90	506·2	454·6	7498	+ 38	7536
	24	11	3 336·5	31·15	507·7	455·6	7504	+ 38	7542

From the above observations were deduced the following results, by comparing swings made at similar pressures, and correcting for slight differences in pressure:

Temperature coefficient (or increase of period for 1° C. increase of temperature).

	A_1	A_2	A_3
	s.	*s.*	*s.*
From observations at low pressures.	·00000359	·00000417	·00000408
From observations at high pressure.	351	417	408
Mean.	·00000355	·00000417	·00000408

The observations with A_1 having been made under unfavorable circumstances, the result for this pendulum is not used, and the mean of the values for A_2 and A_3, or 0·00000412 second per degree, is adopted for all three pendulums. This agrees well with 0·00000414, the coefficient as calculated from the coefficient of expansion of the pendulum alloy, determined by the Office of Standard Weights and Measures, and with 0·00000415, the mean coefficient derived for the second (B) set of these pendulums, made of the same alloy.

The correction to the period is—

$B = 0{\cdot}00000412\ (15^\circ - t^\circ)$, where t° is observed temperature in degrees centigrade.

Pressure correction.—An atmospheric density represented by air at a temperature of 0° C. and under a pressure of 500 millimetres of mercury is taken as a standard, and periods are corrected for the difference between the conditions under which observations were made and this standard. The receiver was always exhausted to a point where the density therein nearly approached the standard, so that this correction is usually quite small. The correction takes the form of

$$C = K\left[\frac{Pr}{1 + {\cdot}00367t} - 500\right]$$

where C is the correction to period in seconds (to be subtracted if observed density is above the standard, or added if density is below standard), K is the pressure coefficient, or variation in period for variation of 1 millimetre in pressure (at 0° C.), Pr is the observed pressure in millimetres of mercury, and t is the mean temperature of swing in degrees centigrade. Values of K were determined at the same time as the temperature coefficients, by the observations already given, from which are deduced the following results:

Pressure coefficient (or increase of period for increase of pressure of 1 millimetre at 0° C.).

	A_1	A_2	A_3
	s.	*s.*	*s.*
From observations at low temperatures.	·000000073	·000000078	·000000077
From observations at high temperatures.	69	78	76
Mean.	·000000071	·000000078	·000000076

The mean of these values, or K = ·000000075 second, was used in the reductions.

Rate correction.—The periods are reduced to sidereal time by correcting for the rate of the chronometer. This may be applied conveniently by the formula,

$$D = 0{\cdot}00001157\ R\ P,$$

where D is correction to period (to be subtracted if timepiece is gaining, added if losing), R is rate of chronometer in seconds per sidereal day, and P is the period of the pendulum.

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Tables.—The reductions were much facilitated and greater accuracy obtained by the use of tables prepared for the purpose, as follows:

1.—Periods, values of P for various values of s in the formula $P = \cdot 5 + \frac{1}{\cdot 4s - 2}$.

2.—Periods when mean-time chronometer was used, formula $P = \cdot 5 - \frac{1}{\cdot 4s + 2}$.

3.—Table of differences to be added to mean time periods to reduce to sidereal time.

4.—Arc correction for various values of φ and φ' (initial and final semi-arc).

5.—Values of $\frac{Pr}{1 + \alpha t}$ for various values of Pr and t.

Correction for flexure of wooden stand.—A strongly braced wooden stand was used as a support for the receiver in which the pendulums were swung, at the following stations: Port Simpson, Juneau, Pyramid Harbor, Yakutat Bay, Wrangell, and for a part of the observations at Burroughs Bay and San Francisco. To determine the effect of any flexure of this wooden stand an extended series of observations was made at San Francisco in July, the receiver being part of the time on a solid (brick) pier, and part of the time on the wooden stand. The means of the corrected periods on each support were as follows:

	Pendulum.		
	A_1	A_2	A_3
	s.	*s.*	*s.*
On pier	·5009151	·5008041	·5007071
On wooden stand	·5009227	·5008104	·5007135
Difference, stand—pier	+·0000076	+·0000063	+·0000064

Mean for three pendulums + ·0000068.

From this it seems evident that the period of the pendulums is lengthened about ·0000068 second by the flexure of the wooden stand, and consequently a correction of — ·0000068 second is made to the mean periods at all stations where the stand was used. The observations at Burroughs Bay on a rock support as well as the wooden stand were not numerous enough, nor made under sufficiently favorable conditions as regards temperature, etc., to give any satisfactory results as to the effect of the stand.

RESULTS.

Notwithstanding the fact that the observations were differential only, it is thought to be more useful and convenient to express the force of gravity at the several stations in dynes per gramme (numerically equal to the acceleration due to gravity), the value at the "base station," which is at the Smithsonian Institution in Washington, being assumed to be 980·10 dynes. This is the best approximation now available and is based on three independent comparisons of this station with that at Hoboken and one unsatisfactory absolute determination. The absolute value at Hoboken is that given by C. S. Peirce in a note in the American Journal of Science, volume 20, page 327, and is derived from observations made with the Repsold reversible pendulum. An earlier determination of absolute gravity near this station was made by Sabine, but it is not made use of in this discussion.

The value obtained by Peirce at Hoboken is

$$g = 980{\cdot}2541$$

Modifying this value by adopting a later and more correct determination of the length of the metre used by Peirce [see pp. 172, 173, Bulletin No. 17, U. S. Coast and Geodetic Survey], it becomes,

$$g = 980{\cdot}2449$$

Based upon this the values at Washington are as follows:

(1) By the new pendulums in 1891, mean of three,

$$g = 980{\cdot}0895$$

(2) Value obtained by C. S. Peirce by comparative swings of the Peirce pendulums,

$$g = 980{\cdot}1017$$

(3) From Col. Herschel's swings of the Kater pendulums in Hoboken and Washington in 1881, mean of three,

$$g = 980{\cdot}1121$$

(4) From absolute determinations at Washington in 1889–'90, by Mr. E. D. Preston, using the Peirce pendulums, but with an unsatisfactory determination of the distance between the knife edges,

$$g = 980{\cdot}05$$

The reduction of the results and their preparation in tabulated form was executed by Mr. Putnam. Preliminary or field reductions of all of the work done on the Pacific Coast and in Alaska were made by Mr. Fremont Morse, and these were checked by Mr. Putnam. To show the nature of the original record, that for a single day is given in table A, but it is not thought desirable to furnish all of the observations in this detail. They are therefore condensed so as to show the conditions for each separate swing, which is believed to be quite sufficient for any examination to which it may be desired to subject them. Table B exhibits these results for all the stations, in chronological order, giving in each case the corrections and the final reduced value of the periodic time. In table C these are collected and the periods at all the stations for each of the three pendulums shown, together with the flexure corrections for the Alaska stations.

Table D shows the value of the force of gravity at all of the stations for each of the three pendulums; and in E the mean values are shown, the stations being separated into two groups, the first including those at which the conditions were sufficiently favorable to justify their being ranked as first-class stations as compared with the others. The values "g" are also shown as reduced to sea level.

As a matter of considerable interest these values have been compared with those derived from Helmert's formula, which is essentially

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the same as that recently published by Harkness. These comparisons, with the excess or deficiency of gravity at each station as compared with that given by the formula, are shown in table F.

At every station the pendulums were swung in direct and reverse positions, the number of swings in the two positions being as far as possible the same. It has often been found, when seconds pendulums have been used, that there was a sensible difference in the vibration periods in the two positions. That no such difference exists with these pendulums is conclusively shown by table G, in which all the periodic times of each pendulum have been collected and the average obtained. It will be seen that at the first-class stations the average direct and reverse periods differ only 1 part in 5,000,000 in the case of pendulums A and A_2, and by 3 parts in 5,000,000 in the case of A_3. This is equivalent to an absolute agreement.

ON THE USE OF A FREE PENDULUM AS A TIME STANDARD.*

The use of the new half-second pendulums has suggested the possibility of employing a pendulum with the improved methods for ascertaining its period in terms of a clock or chronometer second, as a standard of time which in constancy and ease of application might go beyond anything now readily attainable.

The natural though not necessarily invariable unit of time is the sidereal day, and while it is sufficiently constant to satisfy all requirements it is inconveniently long for nearly all operations other than astronomical, in which great precision in time measurement is required. Its subdivision is, therefore, rendered necessary, and this is accompanied by rather more uncertainty than usually belongs to the subdivision of a standard. Even the daily rate of our best clocks and chronometers is by no means constant, and it is safe to say that in most cases little if anything is known regarding their hourly variation from the mean for the day. That such variations, due to fluctuations in temperature, pressure, and other less known causes, exist is well known to all. In the physical, physiological, or other laboratory, in which it is desired to determine intervals of time with a high degree of accuracy, it is common to depend upon the daily rate of chronometer or clock, which rate is itself determined by means of clock signals from an established astronomical observatory, or directly by the use of a transit instrument. In the former, rates are carried during bad weather, and often for many days, by one or more clocks, and with greater or less accuracy, but the signals as received are subject to uncertainty and error arising out of telegraph transmission. In the latter, a few nights in succession of cloudy weather prevent the ob-

*This article was read at the meeting of the National Academy of Sciences in New York, November 11, 1891, essentially as it stands here. Although repeating in some degree what has gone before, it explains in greater detail the use of the flash apparatus in addition to the discussion of the subject proper.

server from getting a rate for his timepiece just when he most needs it. In both cases the daily rate is usually all that is known, although this may differ widely from that existing when the particular experiment was made for which the time is to be standardized. It is believed that a free pendulum, vibrating under constant conditions, furnishes a much more reliable standard for short intervals than any clock or chronometer, and that this standard may be easily utilized by methods about to be described.

The pendulum is for convenience a half-second pendulum, and is, therefore, about a quarter of a metre long. Its mass is only a trifle greater than a kilogram, and the most of this is concentrated in the bob. The knife edge, rigidly attached to the pendulum, is of agate, and it swings upon agate planes. These should be rigidly supported, and may well be secured to a part of the casting which furnishes at once the support for the pendulum and the chamber in which it swings. It should be furnished with a starting and stopping apparatus and an arc for measuring the amplitude of its vibrations. If it is to be used only for comparing chronometers and clocks, no arrangements for securing constant pressure and uniform temperature are necessary. If it is to be a time standard, both should be provided. The first is easy and the second can generally be reached quite closely. Some method of knowing the temperature of the pendulum should be provided. When used under conditions of nearly constant temperature a "dummy" pendulum, in the same inclosure, with a thermometer properly embedded in its stem, will be sufficient. Its amplitude should not be greater than two degrees at first, and when the knife edge is properly prepared it will swing for a couple of hours without this being inconveniently reduced.

The period of the pendulum may be ascertained by means of a modified coincidence method, the elements of which were first applied by Herr Von Sternek in his use of short pendulums in gravity determinations.

A small mirror is placed in a vertical plane on the pendulum head, its center being as near as may be in a horizontal plane passing through the knife edge. A similar mirror is placed parallel to this, and as near to it as possible without interfering with the motion of the pendulum; but it is rigidly attached to the support upon which the pendulum swings. What is called the "flash apparatus" is placed a metre or two metres in front of these mirrors and in a line normal to them. In this an electric spark may be used, or the light of a lamp or candle. What is desired is that a flash of light should be produced every second, as determined by a break-circuit chronometer or clock. For use with a lamp Mr. E. G. Fischer has contrived an ingenious shutter, operated by an electro-magnet, by means of which an illuminated slit is exposed for an instant in the movement following the break only. An induction coil, whose primary circuit is broken by an electro-magnet in the

On the use of a free pendulum as a time standard—Continued.

chronometer circuit, provides the electric flash. Just over the point where this flash is produced is placed a telescope.

When properly adjusted the flash is reflected from both mirrors, and assuming the pendulum to be at rest, two lines of light are seen as one in the telescope, or better, one is made to overlap the other a little. Now suppose the pendulum to be in motion, it will be clear that, as the flash occurs only for an instant each second, whether it will be seen reflected from the moving mirror will depend on the position of that mirror at the instant of its appearance. If it should happen to be in the plane of its original adjustment when the flash occurs, the appearance in the telescope will be precisely the same as when the pendulum is at rest. If the period of the pendulum be precisely one-half of that of the clock or chronometer it will return to this position in just one second and the appearance will be continually repeated. If, however, the pendulum be slightly slow or fast of the chronometer, the mirror will not be precisely in this position at the end of one second and the image from its mirror will be a little above or below that of the first mirror. In another second the distance separating them will be still greater and this will go on until the moving image is no longer seen in the field of the telescope. After a time, however (this period is conveniently about five minutes), the pendulum will have gained or lost one oscillation on the beat of the chronometer, and a few seconds before the necessary period for this has elapsed, the image re-appears in the field and approaches coincidence, to again recede on the other side.

It is only necessary to observe the instant of this coincidence of the two images. Under the conditions mentioned above it is not necessary to observe this closer than the nearest second and only an inexcusably careless observer would ever be a second in error. After having ascertained the "coincidence interval" and observed the first coincidence, the happening of any one in the future can be quite closely predicted. It is desirable to allow the pendulum to swing through a period equal to ten coincidence intervals, and although only the first and last observations may be used it is well to observe two or three at the beginning and end of the period as a check. An idea of the accuracy of the method may be formed by assuming that an error of one second is made in observing the coincidence either at the beginning or end of the swing. It will be seen that the error of the result will be less than 1 part in 2 500 000. As a sample of the uniformity of results which is sometimes attained under favorable conditions, the periods of a pendulum known as A_3 as obtained from a Negus break-circuit sidereal chronometer in three separate sets of vibrations extending through about an hour each, made on the afternoon of October 23, are here given:

First,	·5006279
Second,	·5006281
Third,	·5006280

If such a pendulum be properly cared for there appears to be no reason why, under the same conditions, its oscillation period may not remain sensibly constant for an indefinite period. As an example of constancy during a short period, a little over half a year, but under unfavorable conditions, the following results show the oscillation period of three pendulums as measured in March last and in October. In both cases time is referred to the standard sidereal clock of the U. S. Naval Observatory. Between the first determination and the last, the pendulums traveled about 15,000 miles, were several times landed from a vessel in the surf and with difficulty, and were exposed to great changes of temperature and conditions of weather. The remarkable agreement in the case of all justifies the assumption that a sufficient degree of permanency is attainable.

Date.	Mean periods, Washington.		
	A_1	A_2	A_3
March, 1891,	·5008779	·5007667	·5006702
October, 1891,	·5008759	·5007668	·5006696

When one of these pendulums is compared by means of the flash apparatus above described with a good break-circuit chronometer, it is found to furnish a most delicate test of the equality of the seconds determined by the toothed wheel which breaks the circuit.

Any inequality in the spacing of the teeth or irregularity in the movement of the wheel, of the existence of which the ordinary chronograph record would show no evidence, is clearly and unmistakably shown, and if, on account of bad workmanship, such inequalities are considerable, the result, as viewed in the telescope, is ludicrous, although a chronograph sheet from such a chronometer might present a very good appearance. It will be readily understood that when the breaks are separated by uniform periods, the moving flash will advance regularly and steadily, movements corresponding to one-thousandth of a second in time being easily perceived. When the breaks are irregular, however, the flash moves irregularly at times, standing still for a second or two, and often actually receding. The apparatus may be used, therefore, as a test of the regularity of breaks with chronometers or clocks.

It is often desirable to compare one chronometer with another or with a clock, and to obtain a relative rate. As this rate is variable, it is necessary to determine it by reference to as short an interval of time as possible. The ordinary chronograph record does not give satisfactory results unless the comparison extends over a number of hours or a whole day. By means of the apparatus described, in less than an hour

On the use of a free pendulum as a time standard—Continued.

a daily rate can be determined, correct within about three-hundredths of a second, and a higher degree of accuracy can be secured if it is found desirable.

In this operation it is only necessary to observe coincidences with both chronometers, and then again in forty minutes, or after a longer period, if a better result is wanted. No care need be taken to secure standard conditions of temperature, pressure, etc., as whatever changes may take place affect the coincidence interval of both timepieces alike.

Indeed, it has been found possible to get a fair rate from an observation of a single pair of coincidences, the time consumed being less than five minutes. It is evident that a method is here offered for studying the hourly variations of chronometers and clocks, due to temperature, pressure, or other changes, and in making such investigations the timepiece under examination finds its severest critic not in another of its own kind, but in a free pendulum maintained under uniform standard conditions.

As an example of the comparison of two chronometers by this method the following is cited:

	Chronometers.					
	Negus 1589.			Negus 1518.		
	h.	*m.*	*s.*	*h.*	*m.*	*s.*
First coincidence.	18	17	15	21	07	10
Second coincidence.	19	14	21	22	03	48
Ten coincidence interval.		57	06		56	38

No. 1589 — No. 1518 = 28 seconds.

From which the rate is found to be one second per day.

If the claims here made for the free pendulum are justified, it is likely to find its most useful application as an independent time standard. For this purpose not less than three of these pendulums should be used. They should have slightly different oscillation periods, and these must be determined with great care, under standard conditions and referred to the most accurate mean time second available. Indeed for the first standard set it might be worth while to carry on comparisons during day and night for many days, that all errors incident to the determination of time may be eliminated as far as possible. Assuming the physical constancy of these pendulums and the possibility of reproducing with sufficient accuracy the conditions under which they were swung, no further reference to astronomical observations is necessary, if only the force of gravity does not change. Such a set, or one derived from it, may be issued to any point, with a certificate guaranteeing the periods of oscillation as a simple function of the force of gravity. If the latter is known the oscillation period is at once de-

duced. Whenever it is desired to rate a clock or chronometer it will only be necessary to observe a series of coincidences, using the pendulum and chronometer as described above. The use of three pendulums, whose differences must remain sensibly constant wherever they are, will serve as a check against changes of any kind, and once in a few years a redetermination by means of astronomical time may be had as a further security against systematic error. The ease and accuracy with which their oscillation periods can be determined in terms of the second of a clock or chronometer, and the probable constancy of this period during long intervals of time encourage the belief that the issue of properly authenticated time standards is by no means an impossibility, and as to the desirability of an early accomplishment of such an end there can certainly be no doubt.

ON A TELEGRAPHIC METHOD OF DETERMINING GRAVITY.

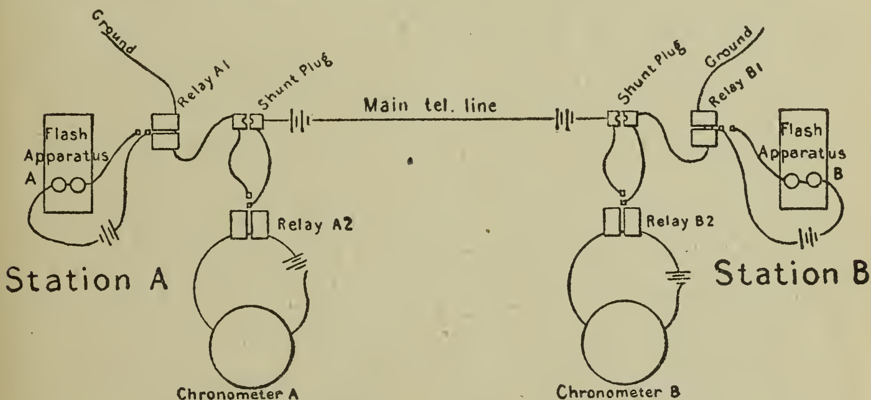
The evident superiority of a free, invariable pendulum as a time measuring device, as compared with the best clocks and chronometers has been frequently noted, and several schemes have been devised for obtaining differential measures of the force of gravity without depending on the accuracy of the latter. It is only necessary to determine the vibration period of the same pendulum in the two places to be compared in some convenient unit of time. It matters not what this unit is, if only it is constant during the comparison. Perhaps nothing approaches nearer to the desired condition of constancy than the vibrations of a free pendulum under constant conditions. Of two such pendulums one may be assumed as the standard and the other compared with it, first, when the two occupy the same station, and second, when one is removed to a distant station. In the latter case the comparison must be made by means of signals transmitted by telegraph. It is convenient to employ a chronometer for the production of flashes at both ends of the line, and the method practically amounts to a comparison of both pendulums with the chronometer *at the same time* so that they are equally affected by any inequalities of the rate of the instrument. It is well to exchange pendulums; only one comparison at the same station is necessary, and in many respects the operation resembles the ordinary method for telegraphic longitude. The results would be subject to error arising from variation in the transmission time of the signals, but this could be practically eliminated by using a chronometer at each end, following a scheme suggested by Mr. Putnam and which he describes as follows:

Suppose the circuit to be made up something as shown in the sketch below, the chronometers working into the main line through relays, arranged so that they may be conveniently shunted out, and the main line working the flash apparatus at either end through relays. Suppose the chronometer A to be working the apparatus at both ends, and one swing to be observed simultaneously with the pendulums A and B, which have about the same period. If the relative periods of pendulums A and B at the base stations be known, we will then have a value for the relative gravity of the two stations A and B. This value will not be affected by the rate of the chronometer A or any variation in the local circuit of this chronometer, as these

On a telegraphic method of determining gravity—Continued.

will affect both stations alike. It will be affected (aside from errors in determination of temperature, etc.), first, by any variation from the beginning to the end of the swing in the transmission time of a second signal; second, by any variation in the local flash apparatus circuits; third, by any irregularity in the break circuit mechanism of the chronometer. The second source of error can probably be made very small by use of a constant battery and by care not to change adjustments during a swing. The third source of error is eliminated by multiplying the number of observations, so that they are distributed over all parts of a minute.

At the beginning of the swing let the transmission time be ·04^s, and at the end of the swing (say one hour later) ·05^s, that is, we will suppose the circuit has varied so that a signal as received at B is delayed ·01^s more at the end than at the beginning of the swing. If this change is unknown and neglected it will enter into the deduced value for relative gravity. The time of the chronometer A as received at station B will practically have a rate of ·01^s per hour (or ·24^s per day) losing, on the time of the chronometer A as used at A. This will cause the eleventh coincidence at B to come seven seconds too late, or make the period of pendulum B to be ·0000014^s (or $\frac{14}{5000000}$ part) too small, and the value of g at B as deduced from this observation will be $\frac{28}{5000000}$ part, or about ·0055 dyne too large.



Any possibility of error from this source could be avoided by using *both chronometers for each swing.* Observer A would cut in his chronometer, and both observers note a coincidence. Chronometer A would then be cut out and B cut in, and both observers note a coincidence with this chronometer. At the end of the swing the same operation would be repeated, and a few intermediate coincidences with each chronometer could be taken as a check. If it is found that the eleventh coincidences with the two chronometers at either station come too near together, the number of coincidence intervals with one chronometer may be made twelve instead of ten, so as to avoid interference.

For every observed swing of the pendulums, there would thus be obtained two relative values of g, entirely independent so far as time arrangements go. Into these two values the error arising from any change in the transmission time would enter with equal amount but with opposite sign, so that it would be eliminated from their mean. Also, as two chronometers are used, any errors due to their irregularities would largely disappear. The time and labor of observing would be but slightly increased.

In the above case it is supposed that the transmission time varied ·01^s in one hour. What variation will actually be met with in practice is difficult to say, but the attached notes of some results obtained in connection with longitude work may throw some light on the subject.

Variation of transmission time.

[From longitude observations, transmission and armature time of signals on different nights. Line, battery, and connections the same each night.]

DETROIT TO CHICAGO.

	s.
July 16	·022
18	·019
19	·022
20	·020
22	·015
23	·020
24	·008
25	·013
27	·021
28	·018

Range in transmission time = ·014 second (about the average).

ALBANY TO DETROIT.

	s.
June 23	·027
24	·026
25	·030
26	·026
27	·030
29	·028
July 4	·024
9	·028
10	·030
11	·026

Range in transmission time = ·006 second (unusually small).

The above are determined from about sixty signals sent each night. There is a very much greater variation between the separate signals, the range in one evening usually being nearly ·100^s, due doubtless to four causes: first, variation of line; second, irregularities of chronometers; third, errors in reading chronograph sheets (difficult to read to ·01^s); fourth, variation in speed of chronograph.

ON A CHANGE IN THE FORM OF THE HALF-SECOND PENDULUMS.

In addition to such modifications of the method of conducting the experiment as will, practically, eliminate errors in time determinations, a somewhat radical change in the form of the pendulum has been suggested since the conclusion of the series of determinations of 1891, and the three pendulums used in that work have been altered in their form with results promising to be entirely satisfactory.

The modification consists in exchanging the places of the knife edge and plane, the latter being placed on the pendulum and the former upon the pendulum support. There are several advantages gained by this arrangement, among which may be mentioned the greatly diminished probability of injury to the pendulum. It is of the utmost importance that these pendulums should be in the fullest sense of the word "invariable," or constant in the quantity and configuration of the matter of which they are composed. The change, and dimensions due to change in temperature, can be experimentally determined and allowed for, and if the pendulums are properly handled and cared for the quantity of matter in each will remain sensibly constant. The chipping of a knife edge may alter the character of a pendulum so much that its period can no longer be compared with that determined before the injury occurred. Such an accident may happen without being detected, and the value of a whole series of swings be destroyed. Clearly, a pendulum which carries no knife edge, but which instead bears a strong block of agate, the lower plane of which rests upon a fixed edge, is much less liable to injury than one of the ordinary form.

On a change in the form of the half-second pendulums—Continued.

Even under the most favorable conditions, with the most careful handling, the edge must become dulled by use. If it be a part of the pendulum, the length of the latter is constantly though slowly increasing. No such effect is produced if the pendulum carries the plane, and, besides, this arrangement makes it possible to regrind an edge, or to use a new one without sensibly affecting the period of the pendulum. There are other advantages which will readily suggest themselves.

As opposed to these there appears but a single difficulty, the disturbing effect of which must, to agree with theory, be small, and which can be sensibly eliminated, as practice has shown. It is the difficulty of fixing the axis about which the pendulum vibrates. This must lie in the agate plane, and should be in one of the principal planes of symmetry and normal to the other. While it is difficult to comply with these conditions rigorously, a close approximation to them may be reached with little trouble, leaving an outstanding error far within the limit which both theory and practice show may be reached without sensibly affecting the period.

A reversible pendulum for absolute measures, whose length is about a quarter of a metre and whose period is approximately half a second, has been designed and is under construction. It is provided with two planes instead of two knife edges, and it is believed that the distance between them can be more accurately measured than would be possible if they were edges. Its total weight will probably be considerably less than a kilogramme; its period will be obtained in a manner similar to that used with the invariable pendulums. The attempt will be made to obtain, at a few base stations, absolute values of the force of gravity of a higher degree of accuracy than those hitherto reached in this country.

NOTE.—A brief statement of the results of the transfer of the Base Station for gravity work, from the Smithsonian Institution to the Office of the Coast and Geodetic Survey, will be found at the end of the following tables, page 563.

TABLE A.

Copy of original record for one day.

[Station, Hoboken, N. J. Date, November 13, 1891. Pendulum, A1. Chronometer, Negus 1824. Observer, T. C. Mendenhall.]

POSITION, DIRECT.

[Temperatures given in brackets are readings of thermometer hanging outside of receiver.]

Swing No.	Coincidences.			Semi-arc.		Thermometer on dummy.	Manometer.		Barometer.	
	No.	Down or up.	Time.	Left.	Right.		Receiver end.	Open end.	Pressure.	Attached thermometer.
			h. m. s.	*mm.*	*mm.*	°*C.*	*mm.*	*mm.*	*mm.*	°*C.*
1	1	D.	21 30 08	5·0	4·3	18·0 [18·3]	119·5	119·0	771·5	18·4
	2	U.	35 02							
	3	D.	39 58							
	4	U.	44 52							
				4·3	3·7	18·0 [18.3]	119·5	119·0	771·6	18·5
	10	U.	22 14 24·5							
	11	D.	19 21							
	12	U.	24 15							
				3·7	3·0	18·2 [18·4]	119·2	118·8	771·7	18·6
2	1	D.	22 46 14	5·0	4·3	18·25 [18·07]	119.2	118·7	772·0	18·7
	2	U.	51 06							
	3	D.	56 02							
	4	U.	23 00 55							
				4·3	3·7	18·3 [18·6]	119·1	118·8	772·1	18·5
	10	U.	23 30 21							
	11	D.	35 18							
	12	U.	40 12							
				3·7	3·0	18·37 [18·6]	119·4	119·0	772·2	18·6
3*	1	D.	23 53 45	5·0	4·2	18·5 [18·7]	119·1	119·0	772·5	18·6
	2	U.	58 38							
	3	D.	0 03 33							
	4	U.	08 26							
				4·3	3·7	18·5 [18·7]	119·0	119·0	772·6	18·5
	10	U.	0 37 50							
	11	D.	42 46·5							
	12	U.	47 39							
				3·8	3·0	18·5 [18·7]	119·0	119·0	772·6	18·5

*E. Smith, observer.

TABLE A—Continued.

Copy of original record for one day—Continued.

[Station, Hoboken, N. J. Date, November 13, 1891. Pendulum A1. Chronometer, Negus 1824. Observer, T. C. Mendenhall.]

POSITION, REVERSED.

[Temperatures given in brackets are readings of thermometers hanging outside of receiver.]

Swing No.	Coincidences.			Semi-arc.		Thermometer on dummy.	Manometer.		Barometer.	
	No.	Down or Up.	Time.	Left.	Right.		Receiver end.	Open end.	Pressure.	Attached thermometer.
			h. m. s.	*mm.*	*mm.*	°*C.*	*mm.*	*mm.*	*mm.*	°*C.*
4	1	D.	1 28 32	4·4	4·8	18·7 [18·9]	118·8	118·0	772·8	18·7
	2	U.	33 23							
	3	D.	38 19							
	4	U.	43 10							
				4·0	4·0	18·7 [18·9]	118·7	118·2	773·0	18·6
	10	U.	2 12 33							
	11	D.	17 30							
	12	U.	22 21·5							
				3·2	3·5	18·7 [18·8]	118·7	118·2	772·8	18·5
5	1	D.	2 36 46	4·5	4·9	18·8 [19.0]	118·5	118·2	772·8	18·7
	2	U.	41 37							
	3	D.	46 33							
	4	U.	51 24·5							
				3·9	4·1	18·75 [18.8]	118·5	118·2	773·0	18·6
	10	U.	3 20 48							
	11	D.	25 44							
	12	U.	30 36·5							
				3·1	3·5	18·75 [18·7]	118·3	118·3	772·8	18·5
6*	1	D.	3 45 33	4·8	4·8	18·75 [18·75]	118·5	118·2	773·0	18·7
	2	U.	50 24							
	3	D.	55 19·5							
	4	U.	4 00 11							
				4·0	4·1	18·75 [18·8]	118·5	118·0	773·0	18·5
	10	U.	4 29 34·5							
	11	D.	34 32							
	12	U.	39 24							
				3·3	3·5	18·75 [18·75]	118·5	118·0	772·8	18·6

* November 14, 1891.

TABLE B.

Pendulum Observations, Washington, D. C. (Smithsonian Institution).

[Support, brick pier. Chronometer, Negus 1824, sidereal.]

Pendulum.	Position.	Swing No.	Date.	Observer.	Ten coincidence intervals.	Semi-arc.		Temperature.	Manometer.	Barometer.	Pressure at 0° C.
						Initial.	Final.				
			1891.		*Seconds.*	*mm.*	*mm.*	°*C.*	*mm.*	*mm.*	*mm.*
A_1	D	1	Mar. 17	Pm.	2 853·0	4·5	3·5	14·57	247·8	773·8	498·1
		2	17	Pm.	2 855·5	4·5	3·5	14·67	247·1	774·1	498·8
		3	17	Pm.	2 858·0	4·5	3·5	14·67	246·2	774·3	499·9
	R	4	17	Pm.	2 856·5	4·5	3·5	14·82	247·6	774·5	498·4
		5	17	Pm.	2 858·5	4·5	3·5	14·92	246·0	774·3	499·5
		6	17	Pm.	2 856·5	4·5	3·5	14·99	244·4	773·5	500·3
A_2	D	7	17	P.	3 264·0	. .	. .	15·12	246·5	772·7	497·5
		8	17	P.	3 260·0	. .	. .	15·27	246·0	771·7	496·6
		9	17	P.	3 260·0	. .	. .	15·27	245·0	771·1	497·0
	R	10	17	P.	3 262·5	. .	. .	15·27	249·0	770·6	492·7
		11	17	P.	3 262·5	. .	. .	15·35	247·7	770·3	493·4
		12	17	Pm.	3 266·0	. .	. .	15·45	247·2	770·4	493·8
A_3	D	13	17	Pm.	3 726·0	. .	. .	15·59	242·0	770·5	498·6
		14	17	Pm.	3 722·0	. .	. .	15·67	239·4	770·5	500·9
		15	17	Pm.	3 721·5	. .	. .	15·67	236·4	770·3	503·6
	R	16	18	Pm.	3 716·5	. .	. .	15·69	238·2	769·9	501·5
		17	18	Pm.	3 717·0	. .	. .	15·75	244·0	769·3	495·3
		18	18	Pm.	3 720·5	. .	. .	15·77	244·7	768·7	494·1

TABLE B—Continued.

Reduction of Pendulum Observations, Washington, D. C. (Smithsonian Institution).

[Periods reduced to temperature 15° C., pressure 500 mm. at 0° C., arc infinitely small, sidereal time.]

Pendulum.	Swing No.	Period uncorrected.	Corrections (in seventh decimal place).				Period corrected.
			Arc.	Temperature.	Pressure.	Rate.	
		s.					s.
A_1	1	·5008778	—56	+18	+1	+57	·5008798
	2	8771	—56	+13	+1	+57	8786
	3	8763	—56	+13	0	+57	8777
	4	8768	—56	+ 7	+1	+57	8777
	5	8761	—56	+ 3	0	+57	8765
	6	8768	—56	0	0	+57	8769
							·5008779
A_2	7	·5007671	—56	— 5	+2	+57	·5007669
	8	7680	—56	—11	+3	+57	7673
	9	7680	—56	—11	+2	+57	7672
	10	7674	—56	—11	+5	+57	7669
	11	7674	—56	—14	+5	+57	7666
	12	7666	—56	—18	+5	+57	7654
							·5007667
A_3	13	·5006719	—56	—24	+1	+57	·5006697
	14	6726	—56	—28	—1	+57	6698
	15	6727	—56	—28	—3	+57	6697
	16	6736	—56	—28	—1	+57	6708
	17	6735	—56	—31	+4	+57	6709
	18	6729	—56	—32	+4	+57	6702
							·5006702

TABLE B—Continued.

Pendulum Observations at various pressures, Washington, D. C. (Smithsonian Institution).

[Support, brick pier. Chronometer, Negus 1824, sidereal.]

Pendulum.	Position.	Swing No.	Date.	Observer.	Ten coincidence intervals.	Semi-arc. Initial.	Semi-arc. Final.	Temperature.	Manometer.	Barometer.	Pressure at 0° C.
			1891.		*Seconds.*	*mm.*	*mm.*	°C.	*mm.*	*mm.*	*mm.*
A_1	D	1	Mar. 18	P.	2 783·2	[4·5]	[3·5]	15·77	0·0	768·6	724·6
	D	2	18	P.	2 786·8			15·77	24·8	768·5	701·2
	D	3	18	P.	2 802·2			15·77	94·0	768·2	635·7
	D	4	18	P.	2 835·0			15·77	262·5	767·9	476·6
	D	5	18	P.	2 821·5			15·97	200·0	767·2	534·5
	D	6	18	Pm.	2 808·5			16·23	152·0	766·2	578·2
A_3	D	7	18	Pm.	3 700·0			16·36	269·3	765·2	466·6
	D	8	18	Pm.	3 680·5			16·60	198·8	764·3	531·7
	D	9	18	Pm.	3 661·0			16·76	152·0	763·9	574·9
	D	10	18	P.	3 639·0			16·83	103·0	763·7	620·6
	D	11	18	P.	3 615·0			16·93	52·1	763·8	668·2
	D	12	18	Pm.	3 594·5			16·98	0·0	763·8	717·0

Reduction of Pendulum Observations at various pressures, Washington, D. C. (Smithsonian Institution).

[Periods reduced to temperature 15° C., pressure 500 mm. at 0° C., arc infinitely small, sidereal time.]

Pendulum.	Swing.	Period uncorrected.	Corrections (in seventh decimal place). Arc.	Temperature.	Pressure.	Rate.	Period corrected.
		s.					*s.*
A_1	1	·5008999	—56	—32	—168	+46	·5008789
	2	8987	—56	—32	—151	+46	8794
	3	8938	—56	—32	—102	+46	8794
	4	8834	—56	—32	+ 18	+46	8810
	5	8876	—56	—40	— 26	+46	8800
	6	8918	—56	—51	— 59	+46	8798
							·5008798
A_3	7	·5006766	—56	—56	+ 25	+46	·5006725
	8	6801	—56	—66	— 24	+46	6701
	9	6838	—56	—72	— 56	+46	6700
	10	6880	—56	—75	— 90	+46	6705
	11	6925	—56	—80	—126	+46	6709
	12	6965	—56	—82	—163	+46	6710
							·5006708

TABLE B—Continued.

Pendulum Observations, San Francisco, Cal.

[Support, brick pier. Chronometer, Negus 1824, sidereal.]

Pendulum.	Position.	Swing No.	Date.	Observer.	Ten coincidence intervals.	Semi-arc. Initial.	Semi-arc. Final.	Temperature.	Manometer.	Barometer.	Pressure at 0° C.
			1891.		*Seconds.*	*mm.*	*mm.*	° *C.*	*mm.*	*mm.*	*mm.*
A_1	D	1	Apr. 10	M.	2 750·0	4·70	3.25	12·74	224·8	754·1	504·7
	R	2	11	Mo.	2 798·0	5·50	4·40	9·75	237·7	755·8	499·5
	D	12	14	Mo.	2 769·0	4·90	3·65	11·15	234·0	754·4	499·0
	D	13	14	Mo.	2 763·6	4·90	3·60	11·35	233·2	754·8	499·9
	R	14	14	Mo.	2 739·0	5·00	3·70	12·69	230·9	755·2	499·8
	R	15	14	Mo.	2 726·8	5·00	3·60	13·33	228·0	755·2	501·6
A_2	D	3	11	Mo.	3 164·4	5·50	3·80	11·05	201·4	756·0	532·0
	R	4	11	Mo.	3 123·5	5·80	4·25	13·18	233·9	755·9	496·8
	D	5	11	Mo.	3 118·6	4·80	3·55	14·19	230·5	755·7	498.0
	D	6	13	Mo.	3 177·7	4·70	3·55	11·14	231·8	751·9	498·7
	R	7	13	Mo.	3 152·4	4·90	3·35	11·79	230·5	752·2	499·2
A_3	D	8	13	Mo.	3 549·2	4·75	3·25	12·98	214·8	752·1	511·8
	D	9	13	Mo.	3 533·4	4·80	3·30	13·73	216·5	752·0	508·7
	R	10	13	Mo.	3 511·0	4·80	3·30	14·87	225·5	752·1	498·1
	R	11	13	Mo.	3 502·2	4·80	3·35	15·32	221·7	752·1	500·9

Reduction of Pendulum Observations, San Francisco, Cal.

[Periods reduced to temperature 15° C., pressure 500 mm. at 0° C., arc infinitely small, sidereal time.]

Pendulum.	Swing No.	Period uncorrected.	Correction (in seventh decimal place). Arc.	Temperature.	Pressure.	Rate.	Period corrected.
		s.					*s.*
A_1	1	·5009108	−55	+93	−4	+57	·5009199
	2	8951	−86	+216	0	+51	9132
	12	9045	−64	+159	+1	+16	9157
	13	9062	−64	+150	0	+16	9164
	14	9144	−67	+95	0	+22	9194
	15	9185	−65	+69	−1	+22	9210
							·5009176
A_2	3	·5007912	−76	+163	−24	+51	·5008026
	4	8017	−89	+75	+2	+55	8060
	5	8029	−61	+33	+2	+55	8058
	6	7880	−60	+159	+1	+23	8003
	7	7943	−60	+132	+1	+23	8039
							·5008037
A_3	8	·5007054	−56	+83	−9	+23	·5007095
	9	7085	−58	+52	−7	+23	7095
	10	7131	−58	+5	+1	+30	7109
	11	7149	−58	−13	−1	+37	7114
							·5007103

TABLE B—Continued.

Pendulum Observations, Port Simpson, B. C.

[Support, wooden stand. Chronometer 2490, mean time.]

Pendulum.	Position.	Swing No.	Date.	Observer.	Ten coincidence intervals.	Semi-arc.		Temperature.	Manometer.	Barometer.	Pressure at 0°C.
						Initial.	Final.				
			1891.		*Seconds.*	*mm.*	*mm.*	°*C.*	*mm.*	*mm.*	*mm.*
A_1	D	1	Apr. 29	M.	3 029·9	5·20	3·70	8·77	247·2	767·1	503·0
	R	2	29	M.	3 057·2	5·15	3·50	10·73	236·9	767·6	509·8
A_2	D	3	29	M.	2 700·0	5·10	3·65	13·95	244·8	768·5	497.1
	R	4	29	M.	2 717·2	5·05	3·75	14·90	245·0	768·5	495·2
A_3	D	5	29	M.	2 459·0	5·10	3·90	15·40	241·2	768·5	497·9
	R	6	29	M.	2 461·5	5·00	3·70	15·40	243·3	768·6	496·0

Reduction of Pendulum Observations, Port Simpson, B. C.

[Periods reduced to temperature 15°C., pressure 500 mm. at 0° C. arc infinitely small, sidereal time.]

Pendulum.	Swing No.	Period uncorrected.		Corrections (seventh decimal place).				Period corrected.
		Mean time.	Sidereal time.	Arc.	Temperature.	Pressure.	Rate.	
		s.	*s.*					*s.*
A_1	1	·4991762	·5005430	—70	+257	—2	—152	·5005463
	2	1836	5503	—65	+176	—7	—152	5455
								·5005459
A_2	3	·4990758	·5004422	—67	+ 43	+2	—152	·5004248
	4	0816	4481	—69	+ 4	+4	—152	4268
								·5004258
A_3	5	·4989854	·5003516	—71	— 16	+2	—152	·5003279
	6	9864	3526	—67	— 16	+3	—152	3294
								·5003286

TABLE B—Continued.

Pendulum Observations, Juneau, Alaska.

[Support, wooden stand. Chronometer 2490, mean time.]

Pendulum.	Position.	Swing No.	Date.	Observer.	Ten coincidence intervals.	Semi-arc. Initial.	Semi-arc. Final.	Temperature.	Manometer.	Barometer.	Pressure at 0° C.
			1891.		*Seconds.*	*mm.*	*mm.*	° *C.*	*mm.*	*mm.*	*mm.*
A_1	D	1	May 11	M.	2 786·8	4·70	3·40	11·56	254·9	762·4	486·0
	R	2	11	M.	2 804·5	4·70	3·45	13·10	244·0	762·0	493·2
	D	11	12	M.	2 799·2	4·60	3·40	12·58	233·0	759·8	502·3
	R	12	12	M.	2 808·5	4·70	3·45	12·95	235·0	759·8	499·9
A_2	D	3	11	M.	2 513·0	4·70	3·55	15·62	233·2	761·5	498·4
	R	4	11	M.	2 536·0	4·55	3·40	17·20	227·3	761·4	501·1
	D	9	12	M.	2 468·2	4·65	3·45	11·41	234·0	759·8	503·8
	R	10	12	M.	2 474·0	4·50	3·55	11·82	239·0	759·8	498·3
A_3	D	5	11	M.	2 318·5	4·60	3·60	18·34	227·7	760·6	497·9
	R	6	11	M.	2 317·2	4·50	3·60	18·00	225·5	760·2	500·3
	R	7	12	M.	2 262·8	4·70	3·65	9·78	241·0	759·4	499·7
	D	8	12	M.	2 267·5	4·65	3·60	10·48	239·8	759·4	499·7

Reduction of Pendulum Observations, Juneau, Alaska.

[Periods reduced to temperature 15° C., pressure 500 mm. at 0° C., arc infinitely small, sidereal time.]

Pendulum.	Swing No.	Period uncorrected. Mean time.	Period uncorrected. Sidereal time.	Corrections (in seventh decimal place). Arc.	Temperature.	Pressure.	Rate.	Period corrected.
		s.	*s.*					*s.*
A_1	1	·4991045	·5004710	−58	+142	+10	−113	·5004691
	2	1102	4767	−58	+ 78	+ 5	−113	4679
	11	1085	4750	−56	+100	− 2	−113	4679
	12	1114	4780	−58	+ 84	0	−113	4693
								·5004686
A_2	3	·4990072	·5003734	−60	− 26	+ 1	−113	·5003536
	4	0161	3824	−56	− 91	− 1	−113	3563
	9	·4989892	3554	−58	+148	− 3	−113	3528
	10	9915	3577	−57	+131	+ 1	−113	3539
								·5003542
A_3	5	·4989240	·5002900	−59	−138	+ 2	−113	·5002592
	6	9235	2895	−58	−124	0	−113	2600
	7	8976	2635	−61	+215	0	−113	2676
	8	8999	2658	−60	+186	0	−113	2671
								·5002635

TABLE B—Continued.

Pendulum Observations, Pyramid Harbor, Alaska.

[Support, wooden stand. Chronometer 2490, mean time.]

Pendulum.	Position.	Swing No.	Date.	Observer.	Ten coincidence intervals.	Semi-arc. Initial.	Semi-arc. Final.	Temperature.	Manometer.	Barometer.	Pressure at 0°C.
			1891.		*Seconds.*	*mm.*	*mm.*	°*C.*	*mm.*	*mm.*	*mm.*
A_1	D	5	May 16	M.	2 757·0	4·65	3·50	11·57	227·0	754·5	505·1
	D	6	16	M.	2 752·5	4·60	3·45	11.54	232·8	755·2	500·4
	R	7	16	M.	2 741·8	4·70	3·50	11·14	233·5	756·0	501·1
	R	8	18	M.	2 725·2	4·50	3·35	9·62	240·7	760·1	500·9
	D	9	18	M.	2 756·0	4·70	3·40	11·32	236·3	760·9	502·9
A_2	D	3	16	M.	2 438·8	4·55	3·45	11·24	232·3	754·6	500·8
	R	4	16	M.	2 441·5	4·55	3·20	11·37	230·5	754·6	502·3
	D	10	18	M.	2 451·2	4·65	3·45	14·00	233·8	761·8	501·2
	R	11	18	M.	2 466·2	4·50	3·30	14·89	235·0	762·3	498·9
	D	14	18	M.	2 457·0	4·60	3·60	14·67	·237·6	763·0	497·4
	R	15	18	Mo.	2 422·8	4·50	3·60	11·86	234·8	763·5	505·8
A_3	D	1	16	M.	2 226·5	4·70	3·60	9·36	234·5	755·4	502·9
	R	2	16	M.	2 234·8	4·65	3·60	10·25	232·3	755·1	503·2
	D	12	18	M.	2 250·5	4·70	3·75	15·35	231·8	762·6	501·4
	R	13	18	M.	2 262·0	4·65	3·65	17·67	234·8	762·9	498·0
	D	16	18	M.	2 205·0	4·65	3·75	9·88	244·2	764·3	501·1
	D	17	18	M.	2 195·2	4·65	3·65	9·00	246·7	764·8	500·8

TABLE B—Continued.

Reduction of Pendulum Observations, Pyramid Harbor, Alaska.

[Periods reduced to temperature 15° C., pressure 500 mm. at 0° C., arc infinitely small, sidereal time.]

Pendulum.	Swing No.	Period uncorrected.		Corrections (in seventh decimal place).				Period corrected.
		Mean time.	Sidereal time.	Arc.	Temperature.	Pressure.	Rate.	
		s.	*s.*					*s.*
A_1	5	·4990949	·5004613	—58	+141	—4	—146	·5004546
	6	0934	4598	—57	+142	0	—146	4537
	7	0898	4563	—59	+159	—1	—146	4516
	8	0843	4508	—54	+222	—1	—146	4529
	9	0945	4610	—58	+152	—2	—146	4556
								·5004537
A_2	3	·4989770	·5003431	—56	+155	—1	—146	·5003383
	4	9781	3443	—53	+150	—2	—146	3392
	10	9822	3484	—58	+ 41	—1	—146	3320
	11	9884	3546	—53	+ 5	+1	—146	3353
	14	9846	3507	—59	+ 14	+2	—146	3318
	15	9702	3364	—58	+129	—4	—146	3285
								·5003342
A_3	1	·4988797	·5002456	—61	+232	—2	—146	·5002479
	2	8838	2497	—60	+196	—2	—146	2485
	12	8916	2575	—62	— 14	—1	—146	2352
	13	8972	2631	—61	—110	+2	—146	2316
	16	8688	2346	—62	+211	—1	—146	2348
	17	8638	2296	—61	+247	—1	—146	2335
								·5002386

Pendulum Observations, Yakutat Bay, Alaska.

[Support, wooden stand. Chronometer 2490, mean time.]

Pendulum.	Position.	Swing No.	Date.	Observer.	Ten coincidence intervals.	Semi-arc.		Temperature.	Manometer.	Barometer.	Pressure at 0° C.
						Initial.	Final.				
			1891.		*Seconds.*	*mm.*	*mm.*	*°C.*	*mm.*	*mm.*	*mm.*
A_1	D	1	May 22	M.	2 776·0	4·70	3·45	16·00	239·3	768·1	498·3
	R	2	22	Mo.	2 755·3	4·50	3·20	14·92	239·7	768·0	499·6
	R	7	22	M.	2 717·2	4·70	3·35	12·00	240·7	766·2	502·4
A_2	D	3	22	M.	2 438·8	4·30	3·20	14·17	240·7	767·8	499·9
	R	4	22	M.	2 452·2	4·40	3·30	14·89	237·2	767·4	501·5
A_3	D	5	22	M.	2 229·0	4·45	3·55	14·30	239·5	766·6	499·8
	D	6	22	M.	2 226·8	4·60	3·65	13·51	238·3	766·5	502·0

TABLE B—Continued.

Reduction of Pendulum Observations, Yakutat Bay, Alaska.

[Periods reduced to temperature 15° C., pressure 500mm. at 0° C., arc infinitely small, sidereal time.]

Pendulum.	Swing No.	Period uncorrected.		Corrections (in seventh decimal place).				Period corrected.
		Mean time.	Sidereal time.	Arc.	Temperature.	Pressure.	Rate.	
		s.	*s.*					*s.*
A_1	1	·4991010	·5004675	—58	— 41	+1	—90	·5004487
	2	0943	4608	—52	+ 3	0	—90	4469
	7	0816	4481	—57	+124	—2	—90	4456
								·5004471
A_2	3	·4989770	·5003431	—49	+ 34	0	—90	·5003326
	4	9826	3488	—52	+ 5	—1	—90	3350
								·5003338
A_3	5	·4988809	·5002468	—56	+ 29	0	—90	·5002351
	6	8798	2457	—60	+ 61	—2	—90	2366
								·5002358

Pendulum Observations, Sitka, Alaska.

[Support, rock. Chronometer 2490, mean time.]

Pendulum.	Position.	Swing No.	Date.	Observer.	Ten coincidence intervals.	Semi-arc.		Temperature.	Manometer.	Barometer.	Pressure at 0° C.
						Initial.	Final.				
			1891.		*Seconds.*	*mm.*	*mm.*	° *C.*	*mm.*	*mm.*	*mm.*
A_1	D	1	May 26	M.	2 804·8	4·55	3·45	11·82	239·0	764·9	503·1
	R	2	26	M.	2 808·8	4·65	3·55	12·23	243·2	765·5	498·9
	D	10	28	M.	2 798·2	4·55	3·30	10·60	244·2	763·0	498·6
	R	11	28	M.	2 812·2	4·60	3·45	11·79	245·0	763·0	495·6
A_2	D	3	26	M.	2 486·0	4·75	3·40	12·22	241·1	765·4	500·8
	R	4	26	M.	2 464·5	4·35	3·50	11·00	241·8	765·6	502·6
	R	5	26	M.	2 463·8	4·50	3·45	10·63	245·8	765·4	499·3
	D	12	28	M.	2 504·8	4·50	3·55	13·85	241·0	762·8	495·5
	R	13	28	M.	2 512·5	4·45	3·45	14·87	248·1	762·7	486·6
A_3	D	6	27	M.	2 259·8	4·60	3·55	9·80	250·3	765·0	496·1
	D	7	27	M.	2 267·5	4·60	3·80	10·47	247·3	765·0	497·8
	R	8	27	M.	2 280·2	4·60	3·55	13·05	239·3	764·2	499·9
	R	9	27	M.	2 284·5	4·55	3·55	13·20	238·3	764·1	500·4

TABLE B—Continued.

Reduction of Pendulum Observations, Sitka, Alaska.

[Periods reduced to temperature 15° C., pressure 500 mm. at 0° C., arc infinitely small, sidereal time.]

Pendulum.	Swing No.	Period uncorrected.		Corrections (in seventh decimal place).				Period corrected.
		Mean time.	Sidereal time.	Arc.	Temperature.	Pressure.	Rate.	
		s.	*s.*					*s.*
A_1	1	·4991102	·5004768	—56	+131	— 2	—90	·5004751
	2	1115	4780	—59	+114	+ 1	—90	4746
	10	1082	4747	—54	+181	+ 1	—83	4792
	11	1126	4791	—57	+132	+ 3	—83	4786
								·5004769
A_2	3	·4989964	·5003626	—58	+115	— 1	—90	·5003592
	4	9876	3538	—54	+165	— 2	—90	3557
	5	9873	3535	—56	+180	+ 1	—90	3570
	12	·4990039	3701	—57	+ 47	+ 3	—83	3611
	13	0070	3732	—55	+ 5	+10	—83	3609
								·5003588
A_3	6	·4988962	·5002622	—59	+214	+ 3	—80	·5002700
	7	8999	2658	—62	+187	+ 2	—80	2705
	8	9060	2720	—59	+ 80	0	—80	2661
	9	9081	2740	—58	+ 74	0	—80	2676
								·5002686

Pendulum Observations, Wrangell, Alaska.

[Support, wooden stand. Chronometer 2490, mean time.]

Pendulum.	Position.	Swing No.	Date.	Observer.	Ten coincidence intervals.	Semi-arc.		Temperature.	Manometer.	Barometer.	Pressure at 0° C.
						Initial.	Final.				
			1891.		*Seconds.*	*mm.*	*mm.*	*°C.*	*mm.*	*mm.*	*mm.*
A_1	D	1	June 1	M.	2 891·8	4·50	3·30	11·46	234·0	758·8	502·8
	R	2	1	M.	2 896·5	4·50	3·25	12·06	240·3	758·8	496·0
	D	12	2	M.	2 932·7	4·60	3·20	16·92	230·3	757·9	495·3
	R	13	2	M.	2 946·2	4·65	3·35	17·61	230·3	757·6	493·9
A_2	D	3	1	M.	2 573·2	4·50	3·15	12·95	236·7	759·4	497·9
	R	4	1	M.	2 563·1	4·30	3·10	12·85	233·5	759·5	501·3
	D	9	2	M.	2 562·2	4·35	3·30	14·07	229·7	759·0	502·1
	R	10	2	M.	2 573·2	4·50	3·25	15·10	234·8	758·9	495·3
	R	11	2	M.	2 580·0	4·40	3·30	15·80	236·5	758·7	492·4
A_3	D	5	1	M.	2 333·7	4·45	3·25	12·76	233·8	760·3	501·8
	R	6	1	M.	2 337·3	4·40	3·35	12·80	233·5	760·1	501·9
	R	7	2	M.	2 331·8	4·45	3·40	10·58	234·3	759·4	504·7
	D	8	2	M.	2 338·5	4·40	3·35	11·59	235·3	759·1	501·4

TABLE B—Continued.

Reduction of Pendulum Observations, Wrangell, Alaska.

[Periods reduced to temperature 15° C., pressure 500 mm. at 0° C., arc infinitely small, sidereal time.]

Pendulum.	Swing No.	Period uncorrected.		Corrections (in seventh decimal place).				Period corrected.
		Mean time.	Sidereal time.	Arc.	Temperature.	Pressure.	Rate.	
		s.	*s.*					
A_1	1	·4991370	·5005035	−53	+146	−2	−60	·5005066
	2	1384	5050	−53	+121	+3	−60	5061
	12	1490	5156	−53	−79	+4	−27	5001
	13	1529	5195	−56	−108	+5	−27	5009
								·5005034
A_2	3	·4990303	·5003966	−51	+84	+2	−60	·5003941
	4	0265	3928	−48	+89	−1	−60	3908
	9	0262	3925	−52	+38	−2	−27	3882
	10	0303	3966	−53	−4	+4	−27	3886
	11	0329	3992	−52	−33	+6	−27	3886
								·5003901
A_3	5	·4989310	·5002970	−52	+92	−1	−60	·5002949
	6	9327	2987	−53	+91	−1	−60	2964
	7	9301	2962	−54	+182	−4	−27	3059
	8	9332	2992	−53	+140	−1	−27	3051
								·5003006

Pendulum Observations, Burroughs Bay, Alaska.

[Support, as designated. Chronometer 2490, mean time.]

Pendulum.	Position.	Swing No.	Date.	Observer.	Ten coincidence intervals.	Semi-arc.		Temperature.	Manometer.	Barometer.	Pressure at 0° C.
						Initial.	Final.				
			1891.		*Seconds.*	*mm.*	*mm.*	*° C.*	*mm.*	*mm.*	*mm.*
A_1*	D	5	June 6	M.	2 952·0	4·70	3·30	9·78	232·7	759·8	508·2
	R	7	6	M.	2 936·2	4·50	3·35	11·12	231·8	760·2	506·7
A_1†	D	6	6	M.	2 932·3	4·50	3·05	10·97	235·2	759·9	503·5
A_2*	D	8	6	M.	2 584·2	4·40	3·30	11·16	241·0	760·2	497·9
A_2†	R	9	6	M.	2 567·0	4·30	3·20	9·73	236·5	760·2	504·9
A_3*	R	1	4	M.	2 436·0	4·50	3·50	17·70	221·5	749·8	494·6
	R	4	4	M.	2 391·2	4·50	3·55	13·85	220·2	749·9	503·1
A_3†	R	2	4	M.	2 436·5	4·50	3·50	16·40	222·7	750·0	496·1
	R	3	4	M.	2 425·0	4·50	3·30	15·22	220·0	750·4	501·1

* On rock. † On wooden stand.

TABLE B—Continued.

Reduction of Pendulum Observations, Burroughs Bay, Alaska.

[Periods reduced to temperature 15° C., pressure 500 mm. at 0° C., arc infinitely small, sidereal time.]

Pendulum.	Swing No.	Period uncorrected.		Corrections (in seventh decimal place).				Period corrected.
		Mean time.	Sidereal time.	Arc.	Temperature.	Pressure.	Rate.	
		s.	*s.*					*s.*
A_1	5	·4991546	·5005212	—56	+215	—6	—25	·5005340
	7	1500	5166	—54	+160	—5	—25	5242
								·5005291
A_1	6	·4991489	·5005155	—50	+166	—3	—25	·5005243
								·5005243
A_2	8	·4990344	·5004008	—52	+158	+2	—25	·5004091
								·5004091
A_2	9	·4990280	·5003943	—49	+217	—4	—25	·5004082
								·5004082
A_3	1	·4989758	·5003420	—56	—111	+4	—50	·5003207
	4	9567	3228	—57	+ 47	—2	—50	3166
								·5003186
A_3	2	·4989760	·5003422	—56	— 58	+3	—50	·5003261
	3	9712	3373	—53	— 9	—1	—50	3260
								·5003260

TABLE B—Continued.

Pendulum Observations, Seattle, Wash.

[Support, stone pier. Chronometer 2490, mean time.]

Pendulum.	Position.	Swing No.	Date.	Observer.	Ten coincidence intervals.	Semi-arc. Initial.	Semi-arc. Final.	Temperature.	Manometer.	Barometer.	Pressure at 0° C.
			1891.		*Seconds.*	*mm.*	*mm.*	°*C.*	*mm.*	*mm.*	*mm.*
A_1	D	1	June 22	M.	3 987·0	4·60	2·90	17·95	225·6	759·2	499·3
	D	2	22	M.	4 008·2	4·50	2·60	17·81	226·0	759·7	499·6
	D	3	22	M.	4 010·3	4·60	2·90	17·73	228·7	759·9	497·4
	R	4	23	Mo.	4 021·5	4·70	3·15	17·48	230·5	760·3	496·5
	R	5	23	Mo.	4 017·5	4·65	3·10	17·31	229·5	760·4	497·9
	R	6	23	Mo.	4 012·2	4·70	3·10	17·21	227·2	760·4	500·2
	D	7	23	Mo.	3 999·5	4·55	2·90	16·96	232·5	760·6	495·8
	D	8	23	Mo.	3 996·3	4·70	2·90	16·81	229·7	760·5	498·7
	D	9	23	Mo.	4 011·5	4·50	3·10	17·00	224·8	760·4	502·8
	R	10	23	M.	4 027·5	4·55	2·65	17·40	233·2	759·9	493·8
	R	11	23	M.	4 041·0	4·45	2·70	17·71	226·7	758·8	498·3
	R	12	23	M.	4 045·3	4·50	2·85	17·85	226·7	758·4	497·9
	D	37	25	M.	4 056·2	4·55	3·10	18·19	229·3	758·3	494·6
	R	38	25	M.	4 069·5	4·40	3·05	18·24	230·2	758·8	494·1
	D	39	25	Mo.	4 078·5	4·80	3·05	18·22	228·3	758·8	495·8
	R	40	25	Mo.	4 077·0	4·75	3·00	18·09	227·7	759·1	496·9
	D	45	26	M.	4 030·2	4·65	2·95	17·73	229·0	758·2	495·5

Reduction of Pendulum Observations, Seattle, Wash.

[Periods reduced to temperature 15° C., pressure 500 mm. at 0° C., arc infinitely small, sidereal time.]

Pendulum.	Swing No.	Period uncorrected. Mean time.	Period uncorrected. Sidereal time.	Corrections (in seventh decimal place). Arc.	Corrections. Temperature.	Corrections. Pressure.	Corrections. Rate.	Period corrected.
		s.	*s.*					*s.*
A_1	1	·4993737	·5007410	−50	−122	+1	− 90	·5007149
	2	3771	7443	−44	−116	0	− 90	7193
	3	3774	7446	−50	−112	+2	− 90	7196
	4	3791	7464	−54	−102	+3	− 99	7212
	5	3785	7458	−52	− 95	+2	− 99	7214
	6	3777	7449	−53	− 91	0	− 99	7206
	7	3757	7430	−49	− 81	+3	−102	7201
	8	3752	7425	−51	− 75	+1	−102	7198
	9	3776	7448	−51	− 82	− 2	−102	7211
	10	3800	7473	−45	− 99	+5	−109	7225
	11	3821	7494	−46	−112	+1	−109	7228
	12	3828	7500	−47	−117	+2	−109	7229
	37	3844	7517	−51	−131	+4	−128	7211
	38	3864	7537	−49	−133	+4	−128	7231
	39	3878	7550	−54	−133	+3	−128	7238
	40	3876	7548	−52	−127	+2	−128	7243
	45	3805	7477	−50	−112	+3	−136	7182
								·5007210

TABLE B—Continued.

Pendulum Observations, Seattle, Wash.

[Support, stone pier. Chronometer, 2490 mean time.]

Pendulum.	Position.	Swing No.	Date.	Observer.	Ten coincidence intervals.	Semi-arc. Initial.	Semi-arc. Final.	Temperature.	Manometer.	Barometer.	Pressure at 0° C.
			1891.		*Seconds.*	*mm.*	*mm.*	°*C.*	*mm.*	*mm.*	*mm.*
A_2	D	13	June 23	M.	3 441·0	4·60	3·10	17·99	225·8	757·7	497·6
	D	14	23	M.	3 443·0	4·55	3·10	17·99	230·5	757·6	493·1
	D	15	23	M.	3 446·5	4·40	3·10	18·14	232·8	757·5	490·5
	R	16	24	Mo.	3 442·8	4·60	3·25	17·86	227·4	756·8	495·5
	R	17	24	Mo.	3 444·0	4·70	3·35	17·68	224·0	756·6	498·6
	R	18	24	Mo.	3 440·3	4·65	3·20	17·51	225·5	756·5	497·6
	D	19	24	Mo.	3 431·2	4·75	3·25	17·15	224·5	756·5	499·1
	D	20	24	Mo.	3 433·5	4·70	3·25	17·05	224·5	756·4	499·3
	D	21	24	Mo.	3 434·2	4·75	3·25	17·01	224·2	756·3	499·6
	R	22	24	M.	3 412·0	4·60	3·15	17·20	226·5	755·4	496·1
	R	23	24	M.	3 422·8	4·60	3·20	17·41	225·5	755·2	496·5
	R	24	24	M.	3 421·0	4·45	3·15	17·65	227·8	755·2	493·9
	D	41	26	Mo.	3 433·5	4·65	3·25	17·13	227·2	759·3	499·3
	R	42	26	Mo.	3 432·8	4·75	3·30	17·11	224·2	759·3	502·1

Reduction of Pendulum Observations, Seattle, Wash.

[Periods reduced to temperature 15° C., pressure 500 mm. at 0° C., arc infinitely small, sidereal time.]

Pendulum.	Swing No.	Period uncorrected. Mean time.	Period uncorrected. Sidereal time.	Corrections (in seventh decimal place). Arc.	Corrections. Temperature.	Corrections. Pressure.	Corrections. Rate.	Period corrected.
		s.	*s.*					*s.*
A_2	13	·4992745	·5006415	—52	—123	+2	—121	·5006121
	14	2749	6419	—51	—123	+5	—121	6129
	15	2757	6426	—49	—129	+7	—121	6134
	16	2749	6419	—54	—118	+3	—142	6108
	17	2752	6421	—57	—110	+1	—142	6113
	18	2744	6414	—54	—103	+2	—142	6117
	19	2725	6394	—56	— 89	+1	—149	6101
	20	2729	6399	—55	— 84	+1	—149	6112
	21	2731	6401	—56	— 83	0	—149	6113
	22	2684	6353	—53	— 91	+3	—139	6073
	23	2707	6376	—53	— 99	+3	—139	6088
	24	2703	6372	—51	—109	+5	—139	6078
	41	2729	6399	—55	— 88	+1	—136	6121
	42	2728	6397	—57	— 87	—2	—136	6115
								·5006109

TABLE B—Continued.

Pendulum Observations, Seattle, Wash.

[Support, stone pier. Chronometer, 2490 mean time.]

Pendulum.	Position.	Swing No.	Date.	Observer.	Ten coincidence intervals.	Semi-arc. Initial.	Semi-arc. Final.	Temperature.	Manometer.	Barometer.	Pressure at 0° C.
			1891.		*Seconds.*	*mm.*	*mm.*	°*C.*	*mm.*	*mm.*	*mm.*
A_3	D	25	June 24	M.	3 032·8	4·60	3·40	17·78	230·0	756·3	492·7
	D	26	24	M.	3 040·2	4·85	3·40	17·85	230·3	756·8	492·8
	D	27	24	M·	3 043·0	4·70	3.40	17·95	225·0	757·0	497·8
	R	28	25	Mo.	3 044·2	4·75	3·55	17·75	225·2	757·3	500·2
	R	29	25	Mo.	3 043·5	4·75	3·40	17·66	227·0	757·4	496·7
	R	30	25	Mo.	3 042·5	4·75	3·50	17·58	223·7	757·6	500·2
	D	31	25	Mo.	3 037·0	4·75	3·40	17·21	223·5	758·2	501·6
	D	32	25	Mo.	3 037·5	4·55	3·35	17·20	224·2	758·3	501·1
	D	33	25	Mo.	3 036·8	4·50	3·30	17·23	222·4	758·3	502·6
	R	34	25	M.	3 023·8	4·60	3·40	17·45	230·5	758·1	494·5
	R	35	25	M.	3 023·0	4·65	3·45	17·71	225·0	757·6	498·7
	R	36	25	M.	3 035·2	4·65	3·50	17·88	223·8	757·3	499·3
	D	43	26	Mo.	3 018·8	4·70	3·35	17·25	229·8	758·9	496·3
	R	44	26	Mo.	3 027·8	4·65	3·40	17·41	224·7	758·6	500·5

Reduction of Pendulum Observations, Seattle, Wash.

[Periods reduced to temperature 15° C., pressure 500 mm. at 0° C., arc infinitely small, sidereal time.]

Pendulum.	Swing No.	Period uncorrected. Mean time.	Period uncorrected. Sidereal time.	Corrections (in seventh decimal place). Arc.	Corrections. Temperature.	Corrections. Pressure.	Corrections. Rate.	Period corrected.
		s.	*s.*					*s.*
A_3	25	·4991770	·5005437	—56	—115	+5	—161	·5005110
	26	1790	5458	—60	—117	+5	—161	5125
	27	1798	5465	—58	—122	+2	—161	5126
	28	1801	5468	—61	—113	0	—169	5125
	29	1799	5466	—58	—110	+2	—169	5131
	30	1797	5464	—60	—106	0	—169	5129
	31	1782	5449	—58	— 91	—1	—166	5133
	32	1783	5450	—55	— 91	—1	—166	5137
	33	1781	5448	—53	— 92	—2	—166	5135
	34	1746	5413	—56	—101	+4	—112	5148
	35	1768	5435	—58	—112	+1	—112	5154
	36	1777	5444	—58	—119	+1	—112	5156
	43	1732	5399	—57	— 93	+3	—136	5116
	44	1757	5424	—57	— 99	0	—136	5132
								·5005133

TABLE B—Continued.

Pendulum Observations, Mount Hamilton, Cal. (Lick Observatory).

[Support, brick pier. Chronometer Negus 1720, sidereal.]

Pendulum.	Position.	Swing No.	Date.	Observer.	Ten coincidence intervals.	Semi-arc. Initial.	Semi-arc. Final.	Temperature.	Manometer.	Barometer.	Pressure at 0° C.
			1891.		*Seconds.*	*mm.*	*mm.*	° C.	*mm.*	*mm.*	*mm.*
A_1	R	1	July 3	M.	2 470·8	4·70	3·60	20·30	113·0	657·2	504·9
	R	2	3	M.	2 473·0	4·75	3·60	20·57	121·8	657·4	496·3
	D	3	3	M.	2 478·0	4·75	3·60	20·75	127·3	657·6	491·1
	D	4	3	Mo.	2 471·0	4·75	3·60	20·98	123·2	657·4	494·3
	R	15	4	M.	2 462·0	4·70	3·50	21·62	119·5	658·1	497·4
A_2	D	5	3	M.	2 771·3	4·65	3·40	21·23	120·8	657·1	495·8
	D	6	3	M.	2 760·0	4·65	3·45	21·43	119·8	656·9	496·2
	R	7	3	M.	2 771·2	4·60	3·40	21·13	126·8	656·8	490·2
	R	8	3	M.	2 767·2	4·55	3·45	21·00	124·5	656·8	492·6
	D	14	4	M.	2 739·0	4·55	3·35	21·82	120·3	657·9	496·1
A_3	D	9	4	M.	3 103·0	4·65	3·30	20·02	125·5	658·2	494·7
	D	10	4	M.	3 093·0	4·50	3·30	20·40	121·8	658·5	498·6
	R	11	4	M.	3 098·5	4·70	3·30	21·05	125·2	658·6	493·5
	R	12	4	M.	3 079·2	4·65	3·35	21·58	112·2	658·3	504·3
	R	13	4	M.	3 079·5	4·65	3·35	21·78	120·2	658·2	496·5

TABLE B—Continued.

Reduction of Pendulum Observations, Mount Hamilton, Cal. (Lick Observatory).

[Periods reduced to temperature 15° C., pressure 500mm. at 0° C., arc infinitely small, sidereal time.]

Pendulum.	Swing No.	Period uncorrected.	Corrections (in seventh decimal place.)				Period corrected.
			Arc.	Temperature.	Pressure.	Rate.	
		s.					*s.*
A_1	1	·5010139	—61	—218	—4	+ 43	·5009899
	2	0130	—61	—229	+3	+ 43	9886
	3	0109	—61	—237	+7	+ 59	9877
	4	0138	—61	—246	+4	+102	9937
	15	0175	—59	—273	+2	+ 65	9910
							·5009902
A_2	5	·5009037	—57	—257	+3	+102	·5008828
	6	9074	—58	—265	+3	+ 87	8841
	7	9038	—56	—253	+7	+100	8836
	8	9051	—56	—247	+6	+ 72	8826
	14	9144	—55	—281	+3	+ 36	8847
							·5008836
A_3	9	·5008070	—55	—207	+4	+ 80	·5007892
	10	8096	—53	—222	+1	+ 78	7900
	11	8081	—56	—249	+5	+ 77	7858
	12	8132	—56	—271	—3	+ 73	7875
	13	8131	—56	—279	+3	+ 87	7886
							·5007882

TABLE B—Continued.

Pendulum Observations, San Francisco, Cal.

[Support as designated. Chronometer 3479, sidereal.]

Pendulum.	Position.	Swing No.	Date.	Observer.	Ten coincidence intervals.	Semi-arc.		Temperature.	Manometer.	Barometer.	Pressure at 0° C.
						Initial.	Final.				
			1891.		*Seconds.*	*mm.*	*mm.*	° C.	*mm.*	*mm.*	*mm.*
A_1*	D	1	July 8	Mo.	2 706·8	4·65	3·55	13·68	230·0	754·5	498·2
	D	2	8	Mo.	2 701·0	4·65	3·45	14·04	230·0	754·7	497·9
	R	3	8	Mo.	2 693·0	4·65	3·50	14·72	234·7	754·8	492·2
	R	4	8	Mo.	2 674·5	4·60	3·50	16·04	226·7	755·1	497·8
	R	8	9	Mo.	2 648·0	4·60	3·45	17·11	222·7	756·3	500·8
	R	10	9	Mo.	2 628·3	4·45	3·45	20·32	221·0	756·2	496·4
	D	11	10	Mo.	2 665·0	4·70	3·55	15·84	220·8	755·4	504·0
	D	13	10	Mo.	2 648·0	4·60	3·40	17·43	224·7	755·2	497·2
	R	30	14	Mo.	2 660·5	4·80	3·70	16·56	221·5	753·5	500·3
A_1†	D	5	8	Mo.	2 624·8	4·70	3·50	18·81	222·2	755·5	497·4
	D	6	8	Mo.	2 618·5	4·70	3·45	19·47	218·3	755·1	499·5
	R	7	9	Mo.	2 644·0	4·65	3·45	16·62	227·7	755·8	496·3
	R	9	9	Mo.	2 607·7	4·70	3·40	19·03	220·3	756·4	499·6
	D	12	10	Mo.	2 638·5	4·65	3·45	16·32	222·7	755·3	501·3
	D	14	10	Mo.	2 607·8	4·70	3·55	18·43	224·7	755·1	495·4
	R	29	14	Mo.	2 663·8	4·85	3·60	15·69	231·7	753·9	492·5

* On pier.
† On wooden stand.

TABLE B—Continued.

Reduction of Pendulum Observations, San Francisco, Cal.

[Periods reduced to temperature 15° C., pressure 500 mm. at 0° C., arc infinitely small, sidereal time.]

Pendulum.	Swing No.	Period uncorrected.	Corrections (in seventh decimal place).				Period corrected.
			Arc.	Temperature.	Pressure.	Rate.	
		s.					*s.*
A_1	1	·5009253	—59	+ 54	+1	—112	·5009137
	2	9273	—58	+ 40	+2	—111	9146
	3	9301	—58	+ 12	+6	—124	9137
	4	9365	—58	— 43	+2	—135	9131
	8	9459	—57	— 87	—1	—143	9171
	10	9530	—55	—219	+3	—135	9124
	11	9398	—60	— 35	—3	—124	9176
	13	9459	—56	—100	+2	—135	9170
	30	9414	—64	— 64	0	—123	9163
							·5009151
A_1	5	·5009542	—59	—157	+2	—114	·5009214
	6	9565	—58	—184	0	—132	9191
	7	9473	—58	— 67	+3	—129	9222
	9	9605	—58	—166	0	—128	9253
	12	9493	—58	— 54	—1	—140	9240
	14	9605	—60	—141	+3	—152	9255
	29	9403	—63	— 28	+6	—104	9214
							·5009227

Pendulum Observations, San Francisco, Cal.

[Support as designated. Chronometer 3479, sidereal.]

Pendulum.	Position.	Swing No.	Date.	Observer.	Ten coincidence intervals.	Semi-arc.		Temperature.	Manometer.	Barometer.	Pressure at 0° C.
						Initial.	Final.				
			1891.		*Seconds.*	*mm.*	*mm.*	°*C.*	*mm.*	*mm.*	*mm.*
A_2*	D	17	July 11	Mo.	3 043·0	4·60	3·40	14·60	230·0	754·4	496·5
	D	18	11	Mo.	3 003·8	4·60	3·45	16·58	226·3	753·8	495·9
	R	20	11	Mo.	2 970·5	4·50	3·45	19·87	221·7	752·6	493·2
	R	27	14	Mo.	3 043·5	4·80	3·50	14·72	224·3	754·4	501·7
A_2†	D	15	10	Mo.	2 948·2	4·70	3·35	18·96	228·7	754·7	490·2
	D	16	11	Mo.	3 039·5	4·70	3·40	13·97	228·3	754·2	499·1
	R	19	11	Mo.	2 968·0	4·55	3·35	18·36	226·7	753·2	491·9
	R	28	14	Mo.	3 016·0	4·75	3·45	14·95	225·0	754·4	500·6
A_3*	D	21	13	Mo.	3 476·0	4·50	3·25	15·64	229·7	753·5	494·1
	D	24	13	Mo.	3 392·0	4·70	3·35	18·15	221·7	753·0	496·7
	R	26	14	Mo.	3 448·2	4·80	3·25	14·79	224·0	754·4	500·1
A_3†	D	22	13	Mo.	3 438·8	4·50	3·15	16·20	224·7	753·6	498·0
	D	23	13	Mo.	3 395·8	4·75	3·35	17·11	222·5	753·4	498·1
	D	25	13	Mo.	3 335·0	4·80	3·40	19·27	221·8	752·7	494·4

* On pier. † On wooden stand.

TABLE B—Continued.

Reduction of Pendulum Observations, San Francisco, Cal.

[Periods reduced to temperature 15° C., pressure 500 mm. at 0° C., arc infinitely small, sidereal time.]

Pendulum.	Swing No.	Period uncorrected.	Corrections (in seventh decimal place).				Period corrected.
			Arc.	Temperature.	Pressure.	Rate.	
		s.					*s.*
A_2	17	·5008229	—56	+ 16	+3	—158	·5008034
	18	8337	—57	— 65	+3	—165	8053
	20	8430	—56	—201	+5	—151	8027
	27	8228	—60	+ 12	—1	—129	8050
							·5008041
A_2	15	·5008494	—57	—163	+7	—165	·5008116
	16	8238	—58	+ 42	+1	—134	8089
	19	8437	—55	—138	+6	—149	8101
	28	8303	—59	+ 2	0	—134	8112
							·5008104
A_3	21	·5007202	- 53	— 26	+4	— 81	·5007046
	24	7381	—57	—130	+2	—118	7078
	26	7261	—57	+ 9	0	—125	7088
							·5007071
A_3	22	·5007281	—51	— 49	+2	— 66	·5007117
	23	7373	—58	— 87	+1	— 99	7130
	25	7508	—59	—176	+4	—120	7157
							·5007135

TABLE B—Continued.

Pendulum Observations, St. Paul Island, Alaska.

[Support, large block of wood. Chronometer 2490, mean time.]

Pendulum.	Position.	Swing No.	Date.	Observer.	Ten coincidence intervals.	Semi-arc.		Temperature.	Manometer.	Barometer.	Pressure at 0° C.
						Initial.	Final.				
			1891.		*Seconds.*	*mm.*	*mm.*	° *C.*	*mm.*	*mm.*	*mm.*
A_1	D	1	Aug. 6	M.	2 782·5	4·50	3·30	12·10	237·0	758·2	498·1
	D	2	6	M.	2 780·0	4·40	3·30	11·90	241·9	758·1	493·6
A_2	D	3	6	M.	2 457·2	4·70	3·30	10·81	234·7	756·9	501·5
	D	4	6	M.	2 455·0	4·60	3·40	10·47	233·6	756·9	503·2
A_3	D	5	7	M.	2 242·5	4·85	3·95	10·72	226·3	756·0	508·8
	D	6	7	M.	2 244·0	4·85	3·30	12·15	229·0	756·3	503·8

TABLE B—Continued.

Reduction of Pendulum Observations, St. Paul Island, Alaska.

[Periods reduced to temperature 15° C., pressure 500 mm. at 0° C., arc infinitely small, sidereal time.]

Pendulum.	Swing No.	Period uncorrected.		Corrections (in seventh decimal place).				Period corrected.
		Mean time.	Sidereal time.	Arc.	Temperature.	Pressure.	Rate.	
		s.	*s.*					*s.*
A_1	1	.4991031	.5004696	−53	+119	+1	+58	.5004821
	2	1023	4688	−52	+128	+5	+58	4827
								.5004824
A_2	3	.4989846	.5003508	−56	+173	−1	+58	.5003682
	4	9837	3499	−56	+187	−2	+58	3686
								.5003684
A_3	5	.4988876	.5002535	−68	+176	−7	+58	.5002694
	6	8884	2543	−58	+117	−3	+58	2657
								.5002676

Pendulum Observations, Washington, D. C. (Smithsonian Institution)

[Support, brick pier. Chronometer, Negus 1589, sidereal.]

Pendulum.	Position.	Swing No.	Date.	Observer.	Ten coincidence intervals.	Semi-arc.		Temperature.	Manometer.	Barometer.	Pressure at 0° C.
						Initial.	Final.				
			1891.		*Seconds.*	*mm.*	*mm.*	*°C.*	*mm.*	*mm.*	*mm.*
A_1	D	1	Oct. 21	F.	2 767.8	4.90	3.65	21.10	231.8	765.3	493.3
	D	2	21	F.	2 769.5	4.95	3.70	21.20	228.8	765.5	496.3
	R	3	21	M.	2 771.0	4.70	3.60	21.50	228.3	764.0	494.8
	R	4	21	M.	2 767.0	4.65	3.60	21.67	225.4	763.8	497.1
	R	5	21	M.	2 767.2	4.80	3.55	21.72	225.0	763.7	497.3
A_2	D	6	22	F.	3 154.5	4.80	3.50	21.00	223.5	759.8	496.3
	D	7	22	F.	3 156.0	4.90	3.40	21.10	221.6	759.5	497.6
	D	8	22	F.	3 147.2	4.85	3.60	21.30	220.2	759.1	498.2
	R	9	22	M.	3 144.5	4.80	3.25	21.67	221.6	760.6	497.6
	R	10	22	M.	3 141.0	4.75	3.40	21.70	221.2	760.6	497.9
	R	11	22	M.	3 142.8	4.85	3.45	21.70	221.2	760.7	498.0
A_3	D	12	23	F.	3 604.0	4.85	3.35	20.70	226.7	764.1	497.7
	D	13	23	F.	3 607.0	4.90	3.40	20.77	225.1	763.8	498.9
	D	14	23	F.	3 604.0	4.80	3.50	20.83	223.4	763.2	499.8
	R	15	23	M.	3 594.8	4.75	3.35	21.10	224.2	762.2	497.7
	R	16	23	M.	3 594.5	. .	3.40	21.25	223.1	762.5	498.8
	R	17	23	M.	3 591.5	4.60	3.20	21.40	222.1	762.7	499.6

TABLE B—Continued.

Reduction of Pendulum Observations, Washington, D. C. (Smithsonian Institution).

[Periods reduced to temperature 15° C., pressure 500 mm. at 0° C., arc infinitely small, sidereal time.]

Pendulum.	Swing No.	Period uncorrected.	Corrections (in seventh decimal place.)				Period corrected.
			Arc.	Temperature.	Pressure.	Rate.	
		s.					s.
A_1	1	·5009049	—64	—251	+5	+34	·5008773
	2	9042	—66	—255	+3	+34	8758
	3	9038	—61	—268	+4	+40	8753
	4	9051	—60	—275	+2	+39	8757
	5	9051	—61	—277	+2	+39	8754
							·5008759
A_2	6	·5007938	—60	—247	+3	+33	·5007667
	7	7934	—60	—251	+2	+32	7657
	8	7956	—63	—260	+1	+32	7666
	9	7963	—57	—275	+2	+36	7669
	10	7972	—58	—276	+2	+39	7679
	11	7967	—60	—276	+2	+40	7673
							·5007668
A_3	12	·5006946	—59	—235	+2	+52	·5006706
	13	6941	—60	—238	+1	+56	6700
	14	6946	—60	—240	0	+55	6701
	15	6964	—58	—251	+2	+41	6698
	16	6964	—58	—258	+1	+35	6684
	17	6971	—53	—264	0	+35	6689
							·5006696

TABLE B—Continued.

Pendulum Observations, Hoboken, N. J.

[Support, brick pier. Chronometer, Negus 1824, sidereal.]

Pendulum.	Position.	Swing No.	Date.	Observer.	Ten coincidence intervals.	Semi-arc. Initial.	Semi-arc. Final.	Temperature.	Manometer.	Barometer.	Pressure at 0° C.
			1891.		*Seconds.*	*mm.*	*mm.*	° C.	*mm.*	*mm.*	*mm.*
A_1	D	1	Nov. 13	M.	29 53·0	4·65	3·35	18·06	238·3	771·6	498·8
	D	2	13	M.	29 45·0	4·65	3·35	18·30	238·1	772·1	499·1
	D	3	13	S.	29 41·2	4·60	3·40	18·49	238·0	772·6	499·2
	R	4	13	M.	29 38·2	4·60	3·35	18·69	236·8	772·9	500·2
	R	5	13	M.	29 38·8	4·70	3·30	18·76	236·6	772·9	500·3
	R	6	14	M.	29 39·5	4·80	3·40	18·74	236·6	772·9	500·4
A_2	D	7	14	S.	33 90·0	4·60	3·20	18·56	236·7	774·0	501·7
	D	8	14	S.	33 89·5	4·75	3·15	18·49	236·7	774·4	502·1
	D	9	14	S.	33 89·2	4·65	3·10	18·46	236·6	774·7	502·5
	R	10	14	S.	33 84·2	4·70	3·15	18·46	236·2	775·1	503·2
	R	11	14	S.	33 89·5	4·65	3·05	18·46	236·1	775·1	503·3
	R	12	14	S.	33 85·2	4·70	3·10	18·49	235·1	774·6	503·8
A_3	D	13	14	M.	39 27·2	4·55	2·95	18·49	237·2	773·0	500·3
	D	14	14	M.	39 20·5	4·55	3·10	18·49	236·9	773·4	501·0
	D	15	14	M.	39 19·0	4·55	2·95	18·49	239·8	774·0	498·9
	R	16	14	S.	39 15·2	4·70	3·00	18·49	237·5	774·4	501·4
	R	17	14	S.	39 17·0	4·70	3·05	18·49	235·5	774·7	503·5
	R	18	14	S.	39 20·5	4·65	3·00	18·46	240·0	775·3	499·9

TABLE B—Continued.

Reduction of Pendulum Observations, Hoboken, N. J.

[Periods reduced to temperature 15° C., pressure 500 mm. at 0° C., arc infinitely small, sidereal time.]

Pendulum.	Swing No.	Period uncorrected.	Corrections (in seventh decimal place).				Period corrected.
			Arc.	Temperature.	Pressure.	Rate.	
		s.					*s.*
A_1	1	·5008480	—56	—126	+1	+79	·5008378
	2	8503	—56	—136	+1	+75	8387
	3	8515	—56	—144	+1	+77	8393
	4	8523	—56	—152	0	+77	8392
	5	8521	—56	—155	0	+79	8389
	6	8519	—59	—154	0	+80	8386
							·5008388
A_2	7	·5007386	—53	—147	—1	+85	·5007270
	8	7386	—55	—144	—2	+88	7273
	9	7387	—52	—143	—2	+89	7279
	10	7398	—54	—143	—2	+92	7291
	11	7386	—51	—143	—2	+94	7284
	12	7396	—53	—144	—3	+96	7292
							·5007282
A_3	13	·5006374	—49	—144	0	+98	·5006279
	14	6385	—51	—144	—1	+92	6281
	15	6387	—49	—144	+1	+85	6280
	16	6393	—52	—144	—1	+80	6276
	17	6391	—52	—144	—3	+76	6268
	18	6385	—51	—143	0	+76	6267
							·5006275

TABLE C.

Summary of mean periods of pendulums A_1, A_2, and A_3, with correction for flexure at stations where wooden stand was used, and final corrected periods.

[Reduced to temperature 15° C., pressure 500 mm. at 0° C., infinitesimal arc, sidereal time.]

Station.	Periods, uncorrected for flexure.			Correction for flexure of wooden stand (seventh decimal place).	Final corrected periods.		
	A_1	A_2	A_3		A_1	A_2	A_3
	s.	*s.*	*s.*		*s.*	*s.*	*s.*
1. Washington:							
March.	·5008779	·5007667	·5006702		·5008779	·5007667	·5006702
October.	8759	7668	6696		8759	7668	6696
Mean.					8769	7668	6699
2. San Francisco:							
April.	9176	8037	7103		9176	8037	7103
July (pier).	9151	8041	7071		9151	8041	7071
July (wooden stand).	9227	8104	7135	—68	9159	8036	7067
Mean.					9162	8038	7080
3. Port Simpson.	5459	4258	3286	—68	5391	4190	3218
4. Juneau.	4686	3542	2635	—68	4618	3474	2567
5. Pyramid Harbor.	4537	3342	2386	—68	4469	3274	2318
6. Yakutat Bay.	4471	3338	2358	—68	4403	3270	2290
7. Sitka.	4769	3588	2686		4769	3588	2686
8. Wrangell.	5034	3901	3006	—68	4966	3833	2938
9. Burroughs Bay:							
Rock.	5291	4091	3186		5291	4091	3186
Wooden stand.	5243	4082	3260	—68	5175	4014	3192
Mean.					5233	4052	3189
10. Seattle.	7210	6109	5133		7210	6109	5133
11. Mount Hamilton.	9902	8836	7882		9902	8836	7882
12. St. Paul Island.	4824	3684	2676		4824	3684	2676
13. Hoboken.	8388	7282	6275		8388	7282	6275

TABLE D.

Values of g at stations of 1891, derived from comparisons of mean periods of separate pendulums with periods at Washington, D. C.

[Based on value of *g* at Washington assumed to be 980·1000 dynes.]

San Francisco, Cal.		*Yakutat Bay, Alaska.*		*Seattle, Wash.*	
A_1	979·9461	A_1	981·8107	A_1	980·7105
A_2	·9552	A_2	·8239	A_2	·7105
A_3	·9507	A_3	·8289	A_3	·7137
	979·9507		981·8212		980·7116
Port Simpson, Alaska.		*Sitka, Alaska.*		*Mount Hamilton, Cal.*	
A_1	981·4234	A_1	981·6675	A_1	979·6564
A_2	·4627	A_2	·6987	A_2	·6430
A_3	·4645	A_3	·6730	A_3	·6375
	981·4502		981·6797		979·6456
Juneau, Alaska.		*Wrangell, Alaska.*		*St. Paul Island, Alaska.*	
A_1	981·7267	A_1	981·5902	A_1	981·6458
A_2	·7439	A_2	·6029	A_2	·6611
A_3	·7200	A_3	·5743	A_3	·6770
	981·7302		981·5891		981·6613
Pyramid Harbor, Alaska.		*Burroughs Bay, Alaska.*		*Hoboken, N. J.*	
A_1	981·7850	A_1	981·4852	A_1	980·2493
A_2	·8225	A_2	·5169	A_2	·2511
A_3	·8180	A_3	·4753	A_3	·2661
	981·8085		981·4925		980·2555

TABLE E.

Results of observations made with half-second pendulums at stations in the United States and British Columbia, from March to November, 1891.

[Based on value of g at Washington, D. C. (Smithsonian Institution), assumed to be 980·1000 dynes.]

Station.	Latitude (north).	Longitude (west of Greenwich).	Elevation above mean sea level.	g at station.	g reduced to sea level.
	° ′	° ′	*Feet.*	*Dynes.*	*Dynes.*
Washington, D. C. (Smithsonian Institution).	38 53	77 02	34	[980·1000]	980·1020
San Francisco, Cal.	37 47	122 26	375	979·9507	979·9727
Seattle, Wash.	47 36	122 20	243	980·7116	980·7258
Mount Hamilton, Cal. (Lick Observatory).	37 20	121 39	4 205	979·6456	979·8920
Hoboken, N. J.	40 44	74 02	35	980·2555	980·2576
Port Simpson, B. C.	54 34	130 26	19	981·4502	981·4513
Juneau, Alaska.	58 18	134 24	16	981·7302	981·7311
Pyramid Harbor, Alaska.	59 10	135 26	15	981·8085	981·8094
Yakutat Bay, Alaska.	59 32	139 48	13	981·8212	981·8220
Sitka, Alaska.	57 03	135 20	28	981·6797	981·6813
Wrangell Alaska.	56 28	132 23	23	981·5891	981·5904
Burroughs Bay, Alaska.	55 59	131 16	0	981·4925	981·4925
St. Paul Island Alaska.	57 07	170 19	40	981·6613	981·6636

[The reduction of g to sea level is made by use of formula $\frac{dg}{g} = 2\frac{h}{r}\left[1 - \frac{3}{4}\frac{\delta}{\Delta}\right]$, where h is height of station above mean sea level, r is radius of earth, δ is surface density, Δ is mean density of earth, and $\frac{\delta}{\Delta}$ is assumed to be one-half.]

TABLE F.

Reduction of values of g to sea level by the formula $\frac{dg}{g} = 2\frac{h}{r}\left[1 - \frac{3}{4}\frac{\delta}{\Delta}\right]$ *assuming* $\frac{\delta}{\Delta} = \frac{1}{2}$ *and comparison with g as derived from Helmert's formula* $l = 0^{m}\cdot993549 - \cdot002631 \cos 2\varphi$ [*or* $g = 980\cdot5934 - 2\cdot5967 \cos 2\varphi$].

[h = height of station above sea; r = radius of earth; δ = density of table land; Δ = density of earth (mean); l = length of seconds pendulum; ϕ = latitude of station.]

Station.	φ Latitude (north).		h Elevation.	g	Correction for h.	g at sea level.	g^1 Helmert's formula.	$g - g^{1}$*
	°	′	*Feet.*					*Dynes.*
Washington.	38	53	34	980·1000	+·0020	980·1020	980 0432	+·0588
San Francisco.	37	47	375	979·9507	+·0220	979.9727	979·9462	+·0265
Port Simpson.	54	34	19	981·4502	+·0011	981·4513	981·4445	+·0068
Juneau.	58	18	16	981·7302	+·0009	981·7311	981·7561	—·0250
Pyramid Harbor.	59	10	15	981·8085	+·0009	981·8094	981·8258	—·0164
Yakutat Bay.	59	32	13	981·8212	+·0008	981·8220	981·8549	—·0329
Sitka.	57	03	28	981·6797	+·0016	981·6813	981·6537	+·0276
Wrangell.	56	28	23	981·5891	+·0013	981.5904	981.6052	—·0148
Burroughs Bay.	55	59	0	981·4925	0	981·4925	981·5647	—·0722
Seattle.	47	36	243	980·7116	+·0142	980·7258	980·8287	—·1029
Mount Hamilton.	37	20	4 205	979·6456	+·2464	979·8920	979·9067	—·0147
St. Paul Island.	57	07	40	981·6613	+·0023	981·6636	981·6592	+·0044
Hoboken.	40	44	35	980·2555	+·0021	980·2576	980·2081	+·0495

* + excess; — defect of gravity.

TABLE G.

Effect of position of pendulum.—Mean periods for pendulums in each position for stations of 1891 where more than one swing was made in each position.

Station.	A_1		A_2		A_3		Differences.		
							A_1	A_2	A_3
	D	R	D	R	D	R	D—R	D—R	D—R
First class.									
Washington (March).	·5008787	·5008770	·5007672	·5007663	·5006697	·5006706	+17	+ 9	— 9
San Francisco (April).	9173	9179	8029	8050	7095	7112	— 6	—21	—17
Seattle.	7198	7224	6119	6099	5126	5139	—26	+20	—13
Mount Hamilton.	9907	9898	8839	8831	7896	7873	+ 9	+ 8	+23
San Francisco (July).	9157	9145	8044	8038	7062	7088	+12	+ 6	—26
San Francisco (wooden stand).	9225	9230	8102	8106			— 5	— 4	
Washington (October).	8766	8755	7663	7674	6702	6690	+11	—11	+12
Hoboken.	8386	8389	7274	7289	6280	6270	— 3	—15	+10
Means.	8825	8824	7718	7719	6694	6697	+ 1	— 1	— 3
Second class.									
Juneau.	4685	4686	3532	3551	2632	2638	— 1	—19	— 6
Pyramid Harbor.	4546	4522	3340	3343	2378	2400	+24	— 3	—22
Sitka.	4772	4766	3602	3579	2702	2668	+ 6	+23	+34
Wrangell.	5034	5035	3912	3893	3000	3012	— 1	+19	—12
Means.	4759	4752	3596	3591	2678	2680	+ 7	+ 5	— 2

Transfer of base station from the Smithsonian Institution to the Office of the Coast and Geodetic Survey.

The room in the Smithsonian Institution which, through the kindness of the Secretary, has been, from the beginning of the pendulum operations of the Survey, the "base station" of all of its gravity work, is for several reasons not well suited for this purpose. The principal difficulty was the sensible vibratory movement of the piers, due to the passage of carriages or wagons over the roadway which passes very near the corner of the pendulum room. Experiment having shown that good stability combined with evenness of temperature could be obtained in one of the lowest basement rooms of the Office of the Survey, it was determined to make this the base station for the future. The room was fitted up especially for the work, with a double-walled chamber within the outer walls of the room, in which two large piers were built. Openings through the walls were provided, so that if necessary four pendulums could be swung at one time, the observers with chronometers, flash apparatus, etc., being outside of the pendulum chamber.

The distance between the two stations being almost exactly a mile, one being nearly due west of the other, and the difference of elevation being only a few feet, it might have been assumed with safety that the force of gravity would be sensibly the same, and the vibration periods of the pendulums at the Smithsonian might have been accepted as correct for the Office of the Survey. It was considered best, however, to make an actual comparison of gravity at the two points, and to do this by the method of telegraphic comparison described in this volume. The arrangement of the telegraphic connection was essentially that shown on page 529. The pendulums compared were B_1, which is one of the set used in Honolulu by Mr. Preston, and which carries a knife-edge, and A_4, which is one of the latest form, bearing a plane instead of a knife-edge, the latter being attached ~~to the~~ support. The observers were Mr. Putnam, Subassistant, and Mr. von der Trenck, acting aid. The full report of this interesting work, with details, will be printed in the Report for 1892, but it is desirable to anticipate that by a presentation of the results at this time.

Sets of vibrations were made under three different conditions: First, with both pendulums at the Office; second, with A_4 at the Office and B_1 at the Smithsonian Institution; third, with A_4 at the Smithsonian Institution and B_1 at the Office. By combining these three sets in three ways the excess of the period at the Office was found to be as follows:

	Seconds.
Combining I and II,	·00000066
Combining I and III,	·00000042
Combining II and III,	·00000054
Mean excess,	·00000054

From this, the excess of gravity at the Smithsonian Institution over that at the Office is found to be 0·0021 dyne. The elevation of the pendulum at the Office is nearly five metres greater than that at the Smithsonian Institution.

In the execution of this comparison thirty-one separate simultaneous swings of the two pendulums were made, each swing lasting a little more than an hour. The agreement among the results was most gratifying. The most discordant result differed from the mean by less than one part in one million, and for the excess of period at the Office of the Survey the most discordant value differs from the mean by only one part in two and a half millions. This promises a degree of accuracy in differential gravity work exceeding anything hitherto attained.

UNITED STATES COAST AND GEODETIC SURVEY

APPENDIX No. 16—REPORT FOR 1891—PART II

PROCEEDINGS OF THE TOPOGRAPHICAL CONFERENCE HELD AT WASHINGTON, D. C., JANUARY 18 TO MARCH 7, 1892

APPENDIX No. 16—REPORT FOR 1892.

PROCEEDINGS OF THE TOPOGRAPHICAL CONFERENCE.

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SUPPLEMENTS.

APPENDIX NO. 16—1891.

REPORT OF THE TOPOGRAPHICAL CONFERENCE, CONVENED AT WASHINGTON BY DIRECTION OF THE SUPERINTENDENT IN JANUARY, 1892.

The members of the Topographical Conference, convened under instructions of the Superintendent of the Coast and Geodetic Survey, present the following report of their proceedings and submit a series of appended papers embodying the facts and reasons which have governed them in forming opinions and coming to conclusions on the subjects referred to them.

The Conference met at the Office of the Survey in Washington, on January 18, 1892, and held daily sessions after that date up to March 7, during which time the subjects assigned to committee investigation and discussed in Conference have received consideration and have been acted upon with careful deliberation.

Before taking up special questions, however, it seems important to consider the subject of surveys in the abstract, and not to lose sight of the fact that the business of making and extending them over large areas of territory is not one in the general market of professional competition, and is work seldom undertaken except under National or State auspices. Even in the most general way it is an operation of much magnitude to go over the ground of a large territory. The question of opportunity becomes, therefore, an important factor in determining what shall be the scope and character of a survey. This is apart from the question of "Special Purpose," discussed more fully elsewhere in this report.

The term "cheap survey," unless specially defined, is a misleading one to the general public. There are, of course, in topographical surveys and their resulting maps, as in other works, degrees of value. The enterprises of the day call for reliable information on all practical subjects; and topographical surveys and maps that do not meet these public requirements fail in a respect which is becoming more and more important in the economy of modern improvements. A small percentage of increased expenditure of time and means, *while on the ground*, would secure such results as the true elevation of important lakes and

ponds in their relation to the adjacent country, and the descending grades of streams possibly available for manufacturing power and other incidental purposes of utility. But where only a picture of nature is attempted, and that but crudely, and where the scale of its representation is so small that nothing very definite can be shown, the undertaking of such a project becomes one of questionable economy and expediency, unless it be of some unexplored or comparatively valueless region, or for the purpose of merely geographical maps.

The Conference desires to express emphatic disapproval of any system of field work which permits illustrations beyond the supervision of the topographer, and by which imperfect and inaccurate representations of features professed to be indicated are incorporated with its results as determinations. No such work should be regarded or accepted by the profession as a legitimate topographical survey; nor by those who recognize the importance of what, in the more highly developed countries of Europe, is considered an absolute necessity, viz, the surveying and mapping, with trustworthy accuracy, the public domain.

The members of the Conference were Assistants Henry L. Whiting, R. M. Bache, Augustus F. Rodgers, W. H. Dennis, Cleveland Rockwell, John W. Donn, C. T. Iardella, Herbert G. Ogden, D. B. Wainwright, W. C. Hodgkins, and J. A. Flemer.

Through answers to a circular letter of invitation from the Conference to contribute views on topographical matters, the following named assistants of the Survey became to that extent its coadjutors: Messrs. George Davidson, H. L. Marindin, J. J. Gilbert, F. W. Perkins, E. F. Dickins, W. I. Vinal, and Fremont Morse. To these, as having also sent answers to the same circular letter, may be added Messrs. Charles Junken, A. Lindenkohl, and F. C. Donn, draughtsmen in the Office of the Survey. For these letters see Supplement A.

The following abstract of the proceedings of the Conference records them, as far as possible, in the order in which they occurred.

The Topographical Conference having been called to order on January 18, 1892, with the Superintendent of the Survey, Dr. T. C. Mendenhall, in the chair, he suggested some of the topics which he wished discussed by the Conference.

The Superintendent, upon the close of his address, designated Mr. Henry L. Whiting as chairman of the Conference, and Mr. J. A. Flemer as secretary. The Conference itself, later in the proceedings, appointed Mr. Augustus F. Rodgers, chairman of the committee of the whole.

The duties of the Topographical Conference gradually found their preliminary place in the work of the following committees, the respective resolutions as to whose guidance, coupled with the results reached and presented in each case to the Conference, will be subsequently dealt with.

COMMITTEES OF THE TOPOGRAPHICAL CONFERENCE.

(1) Classification of topography of the United States—Messrs. Ogden, Bache, and Donn.

(2) Merits and defects of topographical instruments—Messrs. Rodgers, Donn, and Ogden.

(3) Classification of topographical field-work—Committee of the Whole.

(4) Methods of United States and Foreign Government surveys—Messrs. Dennis, Donn, Wainwright, Hodgkins, and Flemer.

(5) Uniformity in conventional signs—Messrs. Dennis, Bache, Rockwell, Donn, and Flemer.

(6) Section 4, Superintendent's suggestions—Committee of the Whole.

(7) On rules to govern the topographical surveys in the different typical sections considered—Messrs. Rockwell, Wainwright, and Hodgkins.

(8) Definition of topographical reconnaissance—Messrs. Ogden, Bache, and Donn.

The above list does not represent the order of resolutions by which committees were appointed, some resolutions not necessitating the formation of committees and other resolutions producing only transient ones.

Mention of certain committees is properly omitted from the list because their work was merely preparatory. Such are: The original No. 7 resolution and committee on rules and order of business—Messrs. Rodgers, Wainwright, and Hodgkins; the original No. 16 resolution and committee on list of topographers—Messrs. Iardella and Wainwright, and the original No. 19 resolution and committee on printing and typewriting—Messrs. Bache, Wainwright, and Hodgkins. These committees may evidently, for the reason assigned, be left out of consideration on a list of those including more permanent duty in connection with the Topographical Conference.

There is, however, a notable exception to this rule of excluding mention of committee work which has been merely preparatory, and that is to be found in the original No. 3 resolution and committee "On the Superintendent's suggestions," Messrs. Donn, Dennis, and Flemer. This committee formulated, more precisely than they had at first been set down, the statements of the Superintendent in his opening address before the Topographical Conference. Upon that precision depended the worth of the results obtainable by the Conference through discussion. It thus becomes necessary to mention here not only the work of that committee, but to add the following summary of the statements of the Superintendent, as presented by the committee to the Conference.

SUGGESTIONS BY THE SUPERINTENDENT OF TOPICS FOR DISCUSSION.

(1) Review the present state of the science and art of topography, including the investigation of work done in our own country—
  (*a*) By the Government.
  (*b*) By private individuals.

Also the more recent advances in methods or improvements in instruments in other countries.

(2) Classification or gradation of topographical surveys and the designation of such classes to grades, so that the character of any piece of work may be expressed with reasonable accuracy by a single word, letter, or denomination. This will include a discrimination between a survey and a reconnaissance.

(3) The establishment of uniformity in the use of conventional signs and the use of contours for the representation of characteristic features.

(4) Methods by which work may be rendered more rapid and less expensive, without material loss of accuracy, and methods for cheap topography, securing the highest accuracy attainable with the least expenditure of time and of a given sum of money.

On January 19, at the second session of the Conference, Mr. Bache read, by its request, at the instance of Mr. Ogden, a paper regarded by the Conference as relevant to the last quoted suggestion of the Superintendent. This paper was entitled "The Topography of the Coast and Geodetic Survey, with relation to its Birth, Development, and further possible Differentiation, with a Contribution thereto of a Description of a Practicable Method of Balloon Surveying." This paper is given in full as Supplement B.

We may now, to advantage, proceed to the consideration, in regular order, of the subjects contained in the preceding list of committees; for although the order of reports and discharges of committees does not necessarily conform to that order, the fact is of no moment to the clear presentation and comprehension of the various questions involved. Similarly, the interpolation by the Superintendent of other matter for consideration, during the course of the work of the previously mentioned committees, does not interfere with nor obscure the statement of their results.

ABSTRACTS OF THE REPORTS OF THE COMMITTEES.

Committee No. 1.—Classification of topography of the United States.—Messrs. Ogden, Bache, and Donn.

Resolution presented by Mr. Ogden, under which the committee acted:

That the Chairman appoint a committee of three to report to the Conference a classification of the United States, to be used as units in describing topographical work.

Abstracts of the reports of the committees.

The committee having, first of all, divided the whole area of the United States into two sections—the coast and the interior—then selected in each of these, eight typical sections susceptible, in a general way, of independent topographical treatment, considering the respective types and the character and amount of cultural detail; these two elements together properly indicating approximate scale for surveys and their approximate cost per square mile for particular regions, and reported the following classification:

Coast.—St. Croix River to Delaware Bay (New England System); Delaware Bay to Winyah Bay (Bay System); Winyah Bay to St. Johns River (Bay System); Mississippi Delta (Delta System); Texas (Texas System); Southern California (Pacific Coast System); Northern California (Pacific Coast System); Oregon and Washington (Pacific Coast System).

Interior.—Rolling lands, like New England, etc. (Primary System); Flat lands, like Southern New Jersey, Delaware, etc. (Coastal Plain System); Prairie lands, like Ohio, Indiana, and Illinois (Prairie System); Great Plains of the West (Great Plain System); Plateau Regions of Kentucky and Tennessee (Plateau System); Appalachian Mountains (Appalachian System); Rocky Mountains (Rocky Mountain System); Sierra Nevada Mountains (Southern half, Rocky Mountain System; northern half, including the Cascade Range, Apalachian System).

The report from which the above is taken will be found in Supplement C.

Upon this Committee, No. 1, was also imposed the duty of reporting upon instrumental methods and cost of surveys per square mile referred to hereinafter under Committee No. 3.

Committee No. 2.—Merits and defects of topographical instruments—Messrs. Rodgers, Donn, and Ogden.

Resolution presented by Mr. Rodgers, under which the Committee acted:

That the chairman appoint a committee to examine and report upon merits and defects of instruments in use, and to suggest improvements, if any are deemed necessary, to make topographical instruments more portable and effective.

The appointment of this committee led at once to a thorough examination of the topographical instruments of the Coast and Geodetic Survey by the members of the committee, and to an informal visit by them, for the purpose of examining such instruments, to the Office of the Geological Survey.

The report of the committee indicated the advisability of essaying, in the interests of portability, the introduction of the so-called aluminum bronze in the manufacture of topographical instruments.

Various possible improvements were suggested by the committee with reference to the movement of the plane table and to the alidade. It expressed the desirability of placing the vertical arc of the alidade in a different quadrant of the circle from that which it occupies at present, with the graduation on the edge of the arc, so that in the ordinary position of the observer, aligned with the telescope tube, at its eyepiece, he can, without moving, read the graduation on the arc.

The committee also recommended that, in addition to the usual horizontal lines in the alidade telescope for telemeter measurements, two intermediate half lines be introduced on each side of the middle line for the purpose of enabling the observer to double the distance of determination. It makes mention of the boat telemeter, of Mr. Bache's invention, used for submerged shores of sedge grass, etc.; also of the aneroid barometer, of latest construction, for mountain work; of the distance measure of Oertel & Son; of the odometer, for small scale work, if a reliable form can be found; of the tachygraphometer, if found available upon careful experiment; of the Meissner level, and of an automatic gravity level, if a satisfactory form can be devised.

The committee recommended that the Superintendent be requested to appoint a committee of officers of field experience to determine upon the best kind of paper for field work, and the best adhesive substance, woven fabric, and methods in connection with backing plane-table sheets.

The investigations of the committee were directed to the employment of an alloy of aluminum solely with the view of securing light ness and portability.

A supplemental report of the committee, however, states that aluminum would not be suitable for the rules of alidades. The full report of the committee is given in Supplement D.

Committee No. 3.—Classification of topographical field work—committee of the whole.

Resolution, presented by Mr. Ogden, under which the committee acted:

That a report to the Conference upon a detailed classification of topographical field work, to be based upon the previously ascertained relations (by the committee appointed for the purpose) of the relative difficulties of different regions of the United States, be prepared by the committee of the whole.

This question was afterwards considered by two committees, Messrs. Rockwell, Wainwright, and Hodgkins forming one, and Messrs. Ogden Bache, and Donn the other.

The first of these committees is known as that "on rules to govern topographical surveys in the different typical sections considered."

The second was Committee (as per preceding list) No. 1, which considered the subject of "Instrumental Methods and relative Cost of surveys per square mile," under the resolution of Mr. Bache, as follows:

That a committee be appointed to report on instrumental methods by means of which can be produced, with the necessary trigonometrical basis, topography of the greatest accuracy compatible with a very limited expense of time and money, and to estimate, with reference to different types of country, assuming a scale for each of these types, the relative cost per square mile (of specific type and scale) of the aforesaid triangulation and topography.

Under the auspices of the committee of the whole, sitting on the question of classification of topographical field work, also appears a statement of "Scales of Topographical Surveys of Europe and America."

Abstracts of the reports of the committees.

A paper presented by Mr. Rodgers was entitled "Facts and Possibilities in Topographical Work."

(For Mr. Rockwell's report from the first committee, as finally adopted by the Conference, see Supplement E.)

(For Mr. Donn's report, acting as secretary for the second committee, see Supplement F.)

(For the paper by Mr. Rodgers see Supplement G.)

(For the statement on "Scales of Surveys" see Supplement H.)

Committee No. 4.—Methods of United States and Foreign Government Surveys—Messrs. Dennis, Donn, Wainwright, Hodgkins, and Flemer.

Resolution, presented by Mr. Dennis, under which the committee acted:

That a committee of five (5) be appointed by the chairman to report on the methods of making topographical surveys by the several departments of the United States and Foreign Governments, and to recommend such changes or improved methods, if any, as they may deem of advantage to the work, as now executed by the U. S. Coast and Geodetic Survey.

The report of the committee under the above resolution is necessarily quite voluminous. It consists, first of all, of a paper in the nature of a preamble, by the chairman, Mr. Dennis. In this he concludes by quoting an interesting passage from a contribution on cartography sent to the board by Mr. A. Lindenkohl, on the subject of using the same unit of measure for heights and distances; secondly, of a paper by Mr. Donn, "On critical surveys for special purposes in the United States;" thirdly, of three papers by Mr. Wainwright, "On topographical surveys in the United States," "On the methods of the Coast and Geodetic Survey," and "On topographical surveys in Italy;" fourthly, of two papers by Mr. Hodgkins, "On surveys in England and France," and "Extracts from the report on European topographical maps, by General Derrécagaix, 1889, on Belgium, Denmark, Holland, Portugal, Roumania, Russia, Spain, Sweden, and Norway;" fifthly, of a paper by Mr. Flemer, "On surveys in Germany, Austria, and Switzerland." The investigations by this committee do not develop any methods of work that could be advantageously substituted for those now used in the operations of the Survey.

Two subjects, not having any direct connection with the labors of this committee, arising from the resolution under which it was formed, were placed in the hands of the committee by the Conference—photogrammetry and the method of balloon surveying, suggested by Mr. Bache.

The first of these subjects is presented in an appended paper by Mr. Flemer, entitled "A short historical review of the art of photogrammetry."

A subcommittee of this committee No. 4, consisting of Messrs. Donn, Wainwright, and Hodgkins, was appointed by the chairman to test the value of this method by experiments in the field. It having proved

impracticable to complete these experiments during the session of the Conference, a resolution was passed requesting the Superintendent to authorize their completion after its close.

The second subject is considered in a special report on Mr. Bache's plan for balloon surveying.

(For all these reports, see Supplement I.)

Committee No. 5.—Uniformity in conventional signs—Messrs. Dennis, Bache, Rockwell, Donn, and Flemer.

Resolution, presented by Mr. Rodgers, under which the committee acted.

That section 3 of the Superintendent's suggestions, viz: "Establishment of uniformity in the use of conventional signs," be referred to a committee of five (5) members, to be appointed by the chairman.

The conventional signs referred to relate more particularly to the original than to the published charts of the Survey. As indicated above, by the suggestions of the Superintendent and by the terms of this resolution, the intention was to secure uniformity in the practice of the Survey. But it must not be inferred from this circumstance that the graphical methods of the Survey have ever been lax. The contrary is the fact, both as to the office and the field. But whereas it is easy to secure for the office, where persons are working in close quarters, perfect uniformity in this matter, the case becomes very different where persons are scattered over so vast an area as that of the United States. So, while great uniformity has always obtained, even in the latter case on the Survey, the present endeavor is to be more accurately stated as in the interest of securing for the field still greater uniformity than heretofore in the use of conventional signs on original charts.

From the nature of the subject placed before this committee no formal report in writing was necessary.

The procedure adopted by the committee was to take as a basis the whole range of conventional signs heretofore used on the Survey, cancelling some of them, adding some, and modifying others. The list, as modified in committee, and then finally perfected by the action of the Conference, became the new one, exhibited in Supplement J. (Illustrations 27, 28, 29, and 30.)

Committee No. 6.—Section 4, Superintendent's suggestions—committee of the whole.

Resolution, presented by Mr. Donn, under which the committee of the whole acted:

That the consideration of section 4, viz: "Methods by which work may be rendered more rapid and less expensive," be referred to the committee of the whole.

The conclusions on this subject, first of all discussed in a general way by the Conference, are embodied in the reports of the committee on the "Classification of the Topography of the United States," of which Mr. Ogden was chairman; on the committee on "Rules to govern Topographical Surveys in the different typical sections consid-

Abstracts of the reports of the committees.

ered," of which Mr. Rockwell was chairman; of the committee on "Instrumental methods and relative cost of surveys per square mile," of which Mr. Ogden was chairman; and of the committee which furnished a table of the estimated relative cost of surveys per square mile in typical sections on specified scales, of which Mr. Rodgers was chairman.

The work of the first three of these committees, already mentioned in connection with them, and the work of the last one, whose report will be found in Supplement C, cover the general scope of the matter submitted to the Conference under section 4 of the "Suggestions of the Superintendent."

In other words, these four reports mentioned cover in a general way the requirements submitted by the Superintendent as to "Devising methods by which work may be rendered more rapid and less expensive without material loss of accuracy, and methods for cheap topography, securing the highest accuracy attainable with the least expenditure of time and a given sum of money."

Committee No. 7.—On rules to govern topographical surveys in the different typical sections considered—Messrs. Rockwell, Wainwright, and Hodgkins.

This is the committee mentioned in the second paragraph of this report relating to committee 3 of the list, where its work was spoken of in connection with that of another committee, because the work of the two together covered the resolution requiring "Classification of topographical field work, to be based upon previously ascertained relations of the difficulties of different regions of the United States." (See, as before, Supplement E.)

Committee No. 8.—Definition of topographical reconnaissance—Messrs. Ogden, Bache, and Donn.

This committee, having considered the question above indicated, finally presented the following definition, which proved acceptable to the board:

Topographical reconnaissance is a determination of the topographical features of a region or locality that, if plotted, would represent on a map only a partial development of the salient features of the region.

Upon the appointment of the committee on instruments, Messrs. Rodgers, Donn, and Ogden, these gentlemen, with other members of the board, under a previous informal invitation to that effect, visited the Office of the Geological Survey, with the object of examining any instruments that might prove novel and of utility in any work of the Coast and Geodetic Survey. This visit, according to the report of the members of the committee on instruments, proved so interesting that another group of members of the Topographical Conference took advantage of a general informal understanding to the effect that the officers of the Geological Survey would be pleased at any time to have members of the Conference pay them a visit and examine into such

details as might interest them at the Office of the Geological Survey, and, under the guidance of Messrs. Gannett and Wilson of that Survey, obtained valuable insight into its topographical methods and instruments.

At that time the members of the Topographical Conference had reciprocated the courtesy shown them by the officers of the Geological Survey, and had extended to them, in turn, an informal invitation to visit the Office of the Coast and Geodetic Survey, and it was decided to anticipate the informal return of the visit of the members of the Conference by a formal invitation to their previous entertainers to visit the Conference in session at the Office of the Coast and Geodetic Survey.

To that effect the following resolution, drawn up by Mr. Bache, was passed by the Conference:

Resolved, That the Topographical Conference, convened at the Office of the Coast and Geodetic Survey, by direction of the Superintendent, and having under consideration the general subject of Topography in the United States and foreign countries with reference to methods employed in the execution of that branch of surveying, their merits and their expense, would be pleased to invite the Director of the Geological Survey to delegate such members of his corps as he may wish to select to meet the said Conference at the Office of the Coast and Geodetic Survey, for the purpose of bringing about a useful interchange of experience and views on this subject of interest common to both Surveys.

This resolution, passed February 11, was sent by the chairman of the Conference, with a transmitting letter, to the Superintendent of the Coast and Geodetic Survey, requesting him to forward it to the Director of the Geological Survey.

On February 13 the Superintendent addressed the Conference, expressing his gratification at the action involved in the passage of the resolution above quoted, and his belief that the interchange of views there alluded to would be beneficial for the co-ordinate surveying branches of the Government service.

On February 16, the Conference having been notified that, in response to the invitation conveyed in the resolution, officers of the Geological Survey would present themselves at 2 p. m. of that day, prepared to receive them.

The gentlemen delegated by the Director of the Geological Survey to visit the Conference were Mr. Gannett, Mr. Wilson, Mr. Thompson, and Mr. Baker.

The members of the Conference, after receiving them, and after opening remarks by the chairman, listened to statements made in succession by their guests. After these statements on various points of professional interest had been made, conversation became general throughout the room regarding details suggested by the preceding statements. The meeting came pleasantly to an end with an expression of great mutual gratification.

Immediately upon the withdrawal of the visiting body the Conference

Conference with officers of the Geological Survey.

came formally to order, and Mr. Rodgers offered the following motion, which passed:

That a resolution of thanks to the delegates of the U. S. Geological Survey be passed by the board, and that the same be transmitted to them, through the Superintendent, to-morrow.

Under this motion Mr. Bache offered the following resolution, which passed:

Resolved, That the members of the Topographical Conference of the Coast and Geodetic Survey, now in session, express through the Superintendent of the Survey to the Director of the Geological Survey, and to the officers of that Bureau, delegated by him to visit the Conference, their gratification at the visit to-day of those gentlemen, and their fullest recognition of the valuable results accruing from this meeting for the purpose of an interchange of views as communicating to mutual advantage some of the fruits of experience of the respective Surveys.

On February 19 the chairman presented to the Conference a letter received from Mr. Gannett, setting forth the methods of topographical surveying employed on the Geological Survey in the northeastern division of the work. This letter was a response to inquiries made at the meeting above referred to, between the officers of the two Bureaus. It was read and ordered to be copied in full in the minutes of the Conference.

A paper was subsequently presented by Mr. Ogden, referring to this letter, and to the undesirability of applying the methods described to the seaboard work of the Coast and Geodetic Survey; and the opinion of the Conference on the availability of these methods for the coast work was finally expressed in the following resolution:

Resolved, That in the opinion of the Topographical Conference the methods of Topographical Surveying described by Mr. Henry Gannett, chief topographer of the U. S. Geological Survey, in his letter of February 19 to the chairman of this Conference, would not prove satisfactory and economical in surveying the narrow belt of topography along the coast, to which the work of the Coast and Geodetic Survey has been confined.

Mr. Gannett's letter and Mr. Ogden's comment will be found in Supplement K.

The minutes of the proceedings of the Topographical Conference evidenced, as to its work, that many resolutions were passed looking to improvements of various kinds. Mention of all of them would obviously be out of place in a general report but will be found in the supplements.

PRINCIPAL CONCLUSIONS FORMULATED BY THE CONFERENCE.

The following paragraphs state, in succinct form, the principal conclusions reached by the Conference:

(1) That balloon photography is not applicable for the purposes of a rapid and economical topographical survey.

(2) That the present standard for topographical work along our coasts should be maintained.

(3) Formulates rules for governing topographic work on specified scales for various typical regions, which would produce maps containing the greatest amount of information for the least expenditure of time and money. Also estimates the approximate cost per square mile for such surveys.

(4) That over a sparsely inhabited region a less elaborate survey, costing much less per square mile, could be made, which, though lacking in much desirable information, would prove useful in the development of that region.

(5) That the plane-table is unequaled in its usefulness in every order of work, and names certain other instruments which would be valuable as auxiliaries.

(6) Recommends certain improvements to the plane-table, and advises the appointment of a committee to superintend the same.

(7) That the mean sea level is the most desirable datum plane for elevations in topographical surveys.

(8) Can not recommend any method of making topographical surveys of the coasts that would be an improvement on that now in use in our own service.

(9) That photography may be found at times a useful auxiliary, but under ordinary circumstances can not compete with the plane-table in rapidity, economy, or accuracy.

(10) That the material of our plane-table sheets is susceptible of much improvement, and that the appointment of a committee to experiment in this direction is recommended.

(11) Presents a revised list of conventional signs for field use.

(12) Defines a topographical reconnaissance as "a determination of the topographic features of a region or locality that, if plotted, would represent on a map only a partial development of the salient features of the region."

(13) Recommends the adoption of the metre as the unit for vertical as well as horizontal measures.

(14) That the methods of the Geological Survey, as described by Chief Topographer Gannett, would not prove satisfactory or economical for our coast work.

(15) Recommends that a manual be prepared of all instruments in use by the Coast and Geodetic Survey.

(16) Recommends the preparation of a new table for heights, using the metre instead of the foot, as the unit for elevations. Also a new empirical formula to be devised for computing elevations.

(17) Recommends the continuance of the committee on photographic surveying, that it may conclude its investigations.

(18) That in the opinion of the Conference, topographical surveys, to subserve the greatest number of useful purposes, should not be made on a scale smaller than 1–40000,

RESOLUTIONS OF IMPORTANCE PASSED BY THE CONFERENCE TOWARD THE CLOSE OF ITS SESSIONS.

Three resolutions, passed during the last part of the sitting of the Conference, relate to matters of sufficient general interest to warrant mention of them. One of these was a recommendation to the Superintendent to appoint a permanent committee of three topographers, two of whom should be members of this Conference and one a member of the Instrument Board of the Office, looking to improvements in topographical instruments, and especially to perfecting the plane-table and field sheets. It was also recommended, through a second resolution, that, for the future, mean sea-level should be taken as the datum plane for elevations in the work of the Coast and Geodetic Survey. The third of these resolutions recommends that, for the future work of the survey, the metre be taken as a unit for heights as well as for linear measurements. Following out this last action, the Conference adopted a resolution offered by Mr. Hodgkins, asking for the preparation of a new table of heights on the metric system, and a resolution offered by Mr. Rodgers, suggesting the desirability of a new formula for the ready computation of heights without the use of tables. On the last day of the Conference Mr. Hodgkins submitted a brief and convenient formula for such purposes. (See Supplement L.)

Another important matter was contained in a resolution proposed by Mr. Hodgkins, at the suggestion of Mr. Donn, and adopted by the Conference, requesting the Superintendent to have prepared a handbook of all instruments used in the Survey, with plates and full descriptions of adjustments and methods of use.

A description of the tachymeter and tachygraphometer, translated by Mr. Hodgkins, and a plate illustrating the power of different scales for the delineation of topographical features, prepared by Mr. Donn, matters of interest in connection with the subjects discussed by the Conference, will be found in Supplements M and N.

With these last memoranda of important points, of which the Topographical Conference has taken cognizance, it closes its report in the belief that it has left little untouched in its discussions that is of much moment, and in the hope that its labors in its field of duty will not be unfavorably regarded by those who are by training best fitted to be judges of its work.

Respectfully submitted.

HENRY L. WHITING,
Chairman.

J. A. FLEMER,
Secretary.

WASHINGTON, *March 8, 1892.*

Supplement A.

LETTERS FROM ASSISTANTS AND OTHERS, ADDRESSED TO THE CHAIRMAN OF THE CONFERENCE.

LETTER FROM ASSISTANT GEORGE DAVIDSON.

In response to your letter of January 25 I have drawn up the following memoranda in answer to your suggestions:

CLASSIFICATION OF TOPOGRAPHICAL SURVEYS.

The necessity for this was quickly appreciated on the Pacific coast, where the necessity for promptly presenting results upon an unknown coast of great extent was urgent, and where the character of the orography was altogether different from that of the Atlantic or Gulf of Mexico. In fact, I have visited the coast of no country where the physical difficulties to be overcome are so great as along this seaboard. My first serious experience in this matter was at Cape Flattery in 1852, where Mr. Lawson executed the topography under my direction. All the conditions were novel. A wild, rugged, high, rocky coast exposed to the great and ceaseless swell of the North Pacific, timbered from the edge of the cliffs to the crest line of the hills, impenetrable on account of the dense undergrowth, cut up by deep and irregular gulches, destitute of even Indian trails over any part, and impracticable for the development of a tertiary triangulation with the means at my command. The means of transportation, two canoes. Grit, endurance, and ability in the topographer, and good support from his men. We had no proper classification for the work, and no sign to indicate its character.

I represented the case to Superintendent Bache, but he was averse to changing the methods of execution or of exhibiting topographical details. In 1868 Superintendent Peirce acceded to my proposition to execute certain parts of the mountain topography in less detail than usual, and such work was done by contouring in 40 and 100 foot curves of broader generalization, and exhibited on the original sheets in broken lines or in a different colored ink. In the wild gulches and rugged heads in the seaboard only generalizations are necessary, and on the crest line of the coast mountains, which gives the navigator his landfall, only sufficient accuracy is demanded to give decided expression to the features. The same sheet should, however, exhibit with

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minute accuracy all the details of the shore for a certain distance inland, and the outlying rocks.

Examples of this are given in the topography from Mendocino southward, and of the Santa Lucia Range south of Monterey.

In all this work I believe in general expression being given by contours, and that characteristic features be represented by suggestive conventional signs.

In the topography of the immediate coast line on the Pacific coast, accuracy has been the governing spirit of the work, and as the needs of navigation and of coast commerce have increased, more detailed accuracy has been demanded. Minute accuracy of the position and peculiarities of outlying rocks is essential to secure safer navigation on this seaboard, where dense and long-continuing fogs prevail, and where the coast line may not be seen from less than a mile distant for consecutive weeks. The navigator in command of a coast steamer runs by time and courses—time to minutes and courses to degrees. When his time is up and he has not made his landmark, he heads directly through the fogs toward the shore and picks it up by the rocks, and then continues along the shore carefully until he reaches a rock whose features he knows and whose accuracy of position he has practically verified. I have witnessed this method of navigation frequently.

In the earlier days the heights and forms of the rocks were not noted and many of the smaller rocks were omitted, but the experience from Point Reyes to Punta Arena, where large numbers of chutes, outreaching high wharves, flying trapezes, etc., have been constructed outside the cliffs and rocky islets, demonstrates the value of the minute survey. All these small and dangerous anchorages are approached with some confidence even in foggy weather when the Coast Survey chart locates all the notable visible as well as sunken rocks.

Improvements involving from $10,000 to $50,000 at a single one of these landing places are made upon the basis of the Coast Survey measures.

TOPOGRAPHICAL RECONNAISSANCE OF THE COAST LINE.

In 1868 I proposed to carry a topographical reconnaissance from Cape Flattery southward for the purposes of the coast pilot. The necessity for this survey increased yearly, not only for coast-pilot use, but to locate and connect the mouths of rivers and bays and give a fair outline of the immediate shore line. For a time, coast commerce got ahead of the regular work.

The results obtained by the topographical reconnaissance of 1887 and 1888 were extremely satisfactory in their results and in the smallness of cost. But in each case they were pushed with such personal vigor and ability, such tenacity of purpose and endurance of privation, that they are exhibits of what can be done in an emergency rather

than what is to be done as a regular business. Each party was pretty well "used up" after the performance of 1887.

I affirm with great earnestness and sincere pleasure that no other organized body in the service of the Government or any corporation could have produced the topographers that could have executed the topographical reconnaissance of this coast in 1887 and 1888 in the same time, with the same means, at the same cost, and with as great accuracy as the Coast Survey assistants did.

A similar topographical reconnaissance of the coast line is what will suffice in Alaska for many years, except in special localities; but it will have to be executed in a different manner and with different means and at greater cost, for the shore line is generally impassable.

Charts published from such surveys should have proper designation of the method employed.

Surveys like those of the Santa Barbara Islands have no parallel on the Atlantic coast. The surveys of the islands of Washington Sound have very many difficulties on account of the fierce character of the currents, absence of trails, the foggy weather, and still greater hindrance of smoky weather. Patience, ceaseless watching, avidity in seizing every opening, and rapidity and accuracy of execution can alone accomplish results. Similar work under similar conditions can not be executed with less cost than is done by the conscientious and able officers on that duty.

DETAILED AND MINUTE TOPOGRAPHY.

For special locations, like San Diego, San Francisco, Humboldt, Yaquina, the mouth of the Columbia, etc., the details and accuracy of the survey should be of the most minute character, and exhaust the skill of the topographer; and certain parts should be resurveyed to exhibit changes of shore line effected by natural or artificial causes.

METHODS FOR THE RAPID EXECUTION OF ACCURATE WORK AT A MINIMUM OF COST.

I have already referred to the rapidity of the topographical reconnaissance of Washington and Oregon at a minimum of cost and a maximum of exhaustion of the topographers.

For the general topography of the coast line much is necessarily left to the judgment of the topographer as to details. To locate every post of a telegraph line would be a wicked waste of means and time.

Much depends upon the facility for executing the tertiary triangulation, the number of triangulation stations, and the rapidity and accuracy of the computer.

In some cases, as in the Columbia River bottom, a great deal depends upon the state of the river (there being two freshets annually), and on the state of the low water as to what shall be taken as the shore line of an island whose upper end is well out of water and the lower end

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below the surface, with a very low grade of descent. Much depends on the condition of the atmosphere on the northern coast and in the Puget Sound region, where great fires prevail in the working season, and where I have known the shore line invisible for weeks at a ship's length. All field work must stop, and it can not be done in winter because of continuous adverse weather. This last project was tried by Superintendent Patterson and utterly failed.

Under all the conditions that have prevailed on this coast, I have known the best men, consumed by anxiety, make a weak show of triangulation and topography for the season on account of smoky weather or the prevalence of fogs and rains, or both. While at the south in the same season, all the conditions of the weather would be favorable.

When the character of the work in any locality has been decided upon, the execution must be trusted to the business management, professional ability, and conscientious execution of the officer in charge. When he knows how much money is to be allotted to him for the season he will lay out his plans to get the most out of it. We have now no one on the coast who would not strive to do so. The spirit of honorable rivalry has generally prevailed.

I have no faith in topography that is essentially "cheap."

I have not a particle of faith in any topography where it is published that one party has executed 3 000 square miles in a month.

Finally, I hardly see how the methods of topography as carried out on this coast can be essentially modified. As the survey advances into the wooded regions to the north it will be impracticable to continue the accuracy attained in an open country, and some changes will be necessarily made by each one; but whether these modifications can be formulated is a question that will solve itself. I have known no wastefulness of means, and I know the officers have a pride in the character of their work, and in the amount which they can present for the money allotted to them. It is probable that the doubling of a party of tertiary triangulation and topography will be the first means to decreasing the cost. This was done by me from 1850 onward through the Puget Sound work to 1857; and at Lola, Round Top, Mount Diablo, etc., where topographical sheets were made by the regular triangulation party. It has been done by others.

I am satisfied on one essential point, the Coast and Geodetic Survey cannot sacrifice the minutest accuracy in its methods wherever accuracy is necessary; yet in this case it is a decided advantage in getting the most good work for the least money to "double" a party.

LETTER FROM ASSISTANT HENRY L. MARINDIN.

In answer to your circular letter of January 26, 1892, I beg leave to submit the following:

What shall determine the accuracy and amount of detail to be shown on a topographical survey and, consequently, the cost of the work?

It seems obvious that the requirements for a topographical survey of New York Harbor should not be the measure of what is requisite for a survey of the Florida coast or that of the Gulf of Mexico.

The object to be subserved by the Survey, it seems to me, should determine the accuracy in details and the cost of the work, with the scale to be employed.

Heretofore in many cases the practice has been not to discriminate sufficiently in the scale to be used.

For localities on the coast of Florida and on the Gulf of Mexico scales of 1–30000 to 1–50000 would give ample room to delineate the details necessary to be shown. From this I would except the main harbors and river outlets where larger scales could be used.

For surveys of important harbors like New York, Boston, Portland, etc., the larger scale the better, and here again one is impressed by the object for which the survey is intended.

Taking for instance a survey for the location of pier lines, a smaller scale than 1–1000 should not be entertained; on such a scale the topographer can represent all the minute details so valuable to the engineer, and he can give the actual measurements made with tape or chain along the continuous wharf line expressed in the figures, to be inked in as a part of the plane table data. This requirement is urged because of the fact that a plane table survey, without actual measurements given in figures, and depending for measurements on the accuracy of a changeable scale is not received in evidence before a court of law, but if it shows actual measurements expressed in figures it at once takes its place as a legal document.

Another point to which I beg leave to call your attention is that of the plane of reference for heights and the bench marks to be established by the topographer.

From my experience in the Survey I am of the opinion that the plane of reference should be approximate mean sea level. I say approximate because with the means at his command the topographer could determine no other. High water, or high-water mark, so called, should be discarded as a plane of reference.

The high-water line, as generally defined by the "crest of the beach," is anything but a horizontal plane; its elevation varies with the locality and depends on the exposure of that part of the shore to the wind and storm waves, modified by the existence or absence of bars and shoals off shore.

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Low-water plane for reference is open to the same objections as "high-water mark," with, however, some extenuating circumstances in its favor.

Mean sea level, it would seem, is the least objectionable plane of reference. A very close approximation to mean sea level can readily be obtained by observing a single high and low water on a common tide staff, and by referring the zero of this staff to a bench (all of which can be done by levels with the plane table and alidade with striding level). The plane of reference can be preserved to be referred at some future time to a more accurate mean sea level if the necessity arises.

By noting the heights of this plane of reference on the sheet, together with a description of the bench established by the topographer, the value of the survey will be increased.

LETTER FROM ASSISTANT J. J. GILBERT.

I have just received your circular letter, and although my special attention is now for the first time directed to the objects of discussion before the Conference; and although I have been so long entirely separated from my associates in the Survey, association with whom would, doubtless, have given force and expression to opinions on these subjects which may now lie dormant in my mind; yet, as not wishing to shirk any responsibility, I will venture to make a very general response to your invitation.

On the first topic I have nothing to say; if there has anywhere been any advance in methods or improvement in instruments in the last twenty odd years, I have yet to hear of them.

On the second topic I have little to say; the extremes may well be designated as "survey" and "reconnaissance," but there are many degrees of accuracy between these extremes, owing mechanically to the scale, physically to the character of the country; or the amount of detail may depend upon the object of the survey, or be limited by the expense of time or money; these different grades of work might well be designated so as readily to distinguish them; but to express the distinction by a single word would seem difficult unless words were coined for the purpose; the use of compound words would be simpler, and following the method of distinguishing the triangulation, primary, secondary, and tertiary surveys might with use come to sound very proper.

Third. I believe that the conventional signs should be simple and uniform, but not multiform, as few as is possible. All cultivated land, except perhaps rice fields, may well be represented as grass land; all

coniferous trees by the same sign, one made by three lines crossing, thus ✳, seems more simple, and is easily formed; all deciduous trees by a common sign. I would not attempt to designate sawmills, churches, etc., by any conventional sign, but would print their names on the map. The contours as heretofore used in the Survey seem to meet every requirement, and I can conceive of no improvement.

Fourth. The value of anything has a ratio to its cost. Excellence in any line is not achieved by cheap methods. I do not believe in extravagance, but I do believe that an attempt to do work any cheaper than the conscientious assistant now does it would be unfortunate—this, of course, as to methods; in some of the circumstances of work economy might be practiced, as hiring a horse and saddle instead of team and buggy, when the former would answer every purpose, but this would apply to other classes of work as well as topography.

Now, for an actual comparison of work: Last season I made a survey of the water front of Whatcom and Fairhaven. About one-third of the shore line was very rocky and difficult. A civil engineer made a survey of the water front of Tacoma, all very easy shore line; the amount of work done in each place was approximately the same, probably a mile or two more of shore line at Tacoma; the Whatcom work was finished in six weeks, and, including my own salary, cost about $1,000, somewhat less; the Tacoma work took more than three months and cost over $3,000.

I believe it can be readily demonstrated that good work can be done as readily and cheaply by the Coast Survey method as any other, and, indeed, more rapidly and more economically. If this is true, then the remaining proposition is, shall we do cheap work for the sake of greater economy? I say most emphatically, no. What is worth doing at all is worth doing well. If there is great haste in obtaining results let that work be done quickly, and as a consequence cheaply, and let it be called, what it in truth is, a reconnaissance, and let the careful survey follow in due time.

As to securing the most work and the greatest accuracy with the least expenditure of time and money, this I believe rests mainly upon the assistant in charge of the work, and that is what we should all endeavor to do—it is to be secured by good judgment and by wasting no time.

Recurring briefly to the first topic: I have often had trouble in getting the rodman to hold his rod true, and it has occurred to me that this difficulty might be remedied by a small sight tube screwed through the rod about the height of the eye, and across the lower object end of the tube a small level, so that the rodman could always point the line of sight to the plane table, thus holding the rod perpendicular to the line of sight, while he could at the same time see the level and keep the rod from leaning to one side. Such an appliance could be cheaply made in the Office and readily attached to any rod.

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LETTER FROM ASSISTANT F. W. PERKINS.

I have your communication of the 25th. While I shall take much interest in the results of your deliberations, I am unable to contribute any suggestions for the consideration of the Conference.

I inclose, however, two letters from Mr. J. C. Olmsted, which, although relating to the cost and requirements of topographical work of a special class, may be of interest to you. These letters were written at my request some years ago when engaged in collecting information as to the cost of different classes of topographical work, a subject which was at the time interesting my friends in Rhode Island.

BROOKLINE, MASS., *February 23, 1885.*

* * * Prices of surveys (topographical) made under our direction have ranged from $2.50 to $20 or more per acre.

A well-educated surveyor, handling the instrument himself, and plotting and drawing himself, with two apprentice or cheap-waged assistants, can make a map of open or nearly open ground sufficiently accurate for preliminary estimates of earthwork and general plans of roads, etc., for an average of, say, $5. The best system is by plane-table sheets for topography, I believe, but usually, if the character of the ground admits of it, the whole area is laid out in squares of 100 feet and stakes driven, to which reference is made for location of trees, fences, rocks, and buildings, etc., and which stand till levels are taken at all of them. Ordinarily a good many other levels are taken for the better delineation of the contours—say perhaps twice as many. For our purposes levels should always be taken along existing streets, water levels, ground at doorsteps, floor levels, etc. All trees standing singly or in groups are usually located, and a few of the finest in woods, such as it would be a pity to disregard in planning, where more important considerations did not apply.

Of course it is very difficult to specify with such exactness the character of a survey as to admit of the principle of giving the work to the lowest bidder. The surveyor who lives near the work can usually do the work much cheaper than one who has to pay traveling expenses, so that if the local surveyor is not wretchedly bad and the work very large and important, we usually recommend the employment of the local man. We have had some very queer specimens of draughting and often grossly inaccurate data from such. It is usually more economical to fix upon a rate per acre or a lump sum and leave it to the surveyor to give as much time to it as he can afford to. We find that this usually results in the surveyor saying that he didn't make anything and would have to charge more next time. On the other hand, if the surveyor charges by the day with expenses he is well enough satisfied, but the owner who pays for the work is generally left feeling very sore—that is, it is very easy to make a survey cost a great deal more than the average of $5 which I have mentioned. In park work, where the work is done by hired men, the cost I should judge usually exceeds $10 per acre and sometimes $20.

I send you several lithographic reductions of surveys, which have been made expressly for our purposes. That of "Properties in Newport" cost $3 per acre, and was plotted at 100 feet to an inch. Of course at that price, with such very rough ground, the instrumental work had to be diminished and the sketching on the ground of contours and rocks increased. It has proved entirely satisfactory for its purpose of running streets through and selecting house sites, but in some cases the design has been or will have to be intelligently modified to avoid bad rock cutting and so on. Still it would have been extravagant to have paid much more for a survey for the purpose in view. Part of the streets have been built according to our plan at an average price per running foot ($1.65 including crushed stone roadbed).

The map of "Aspinwall Hill" was an unusually accurate survey, plotted at 100 feet to an inch, but I do not know what it cost.

The map of "Belle Isle" was done by contract at a round sum according to our specifications. It was plotted on sheets at 50 feet to an inch, and also on one sheet at 100 feet to an inch. On the large scale all measurements locating isolated or principal trees, buildings, wharves, etc., were shown, also levels which were taken at every 100 feet, with others where necessary. I can not remember the price paid, but it was low, I should think $1,500 or $2,000.

The map of "West Roxbury Park" was plotted at 100 feet to an inch, as was also that of "Muddy River," both by hired surveyors and draughtsmen under the direction of the city engineer. The party employed on "West Roxbury Park" was in the field over a year and the draughtsmen took months to make the plan so that it must have been very costly. At the same time we find already that the rocks are very inaccurately represented and in many cases not shown at all, and in general the topographical indications can not be implicitly relied upon in the rough, rocky ground, but have to be studied carefully on the ground while planning. The locating of everything that could be measured to with the tape is probably quite accurate, and the leveling also, but a much more valuable map would have been made by a surveyor accustomed to sketching accurately on the ground instead of working up instrumental field notes in the office, and at much less cost.

As to accuracy in general, the boundary and buildings and a few monuments on a place should be located with such accuracy as to permit a plan of roads based on them to be staked out by a different surveyor without any trouble. I should say that errors of measurement of these principal features ought not to exceed one-tenth of 1 per cent on maps at 100-foot scale, but that the minor features, trees, walks, and roads, stone walls, ditches, rocks, etc., might have errors of 1 per cent without causing undue trouble, while the delineation of masses of rock and woods, and the location of contours might be even 2 or 3 feet out. I mean that the main skeleton in most cases should have that degree of accuracy, while the filling in within spaces of a few inches on the map might have the degrees of error mentioned. The rendering of a map for reducing should be much stronger and less detailed than is usual. The Muddy River plan is clear and simple, although reduced, I think, from 100 to 300 feet to an inch, while the tracing for West Roxbury had to be set aside and a new one made because it was too fine in the lines to bear one-half reduction.

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J. C. OLMSTED.

BROOKLINE, MASS., *May 24, 1885.*

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I returned Hodgkins letter as you wished. Did you wish the maps returned also?

He refers to an extreme cost of surveys when he mentions $20 per acre. Of course these are rare cases and represent an amount of detail such as he probably has had no experience of. It includes, for instance, the location of every tree, with notes as to species, spread of branches, and diameter of trunk, also delineation of all rocks and bowlders and accurate measurements of houses and all artificial features, and test pits to show the depth and character of soil, besides very numerous levels and 1-foot contours and drawn on a scale of 20 or 30 feet to an inch. Of course what is done for a given price must be very carefully specified, and even then there is no guaranty practically as to the accuracy of all of the work besides the known honesty of character of the surveyor. We consider a good plane-table survey the best, but for convenience of subsequently staking out work the surveys are usually made by staking out the whole ground into 25, 50, or 100 feet squares, as the case may be, in which case the levels and trees, etc., are determined by measurement from these stakes. If the price is excessive it must mean that too large a profit is charged or that the work is not done by the cheapest method, of course assuming that the quality of the result is first rate. Wages of surveyors I believe run from $2 to $10 per day. When the jobs are small in extent, rarely covering over 500 acres, more often only 20 or 30 to 50 acres, the office rent, profit for general superintend-

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ence, and expenses of all kinds (stakes and fences) must be covered. The fair, ordinary cost for a quality of survey such as suits our purposes is generally about $5 per acre.

The survey is generally made cheapest by the surveyor who lives nearest the ground and who handles the instruments himself.

J. C. OLMSTED.

LETTER FROM ASSISTANT E. F. DICKINS.

In reply to yours of the 25th ultimo, I beg leave to submit the following for your consideration:

For a general coast chart, where the geographical positions of the principal headlands have been determined by astronomical stations and are not yet connected by triangulation, the intervening coast line and topography can be put in rapidly and with sufficient accuracy by a plane-table reconnaissance, such as was made by Assistants Rockwell, Pratt, and myself, along the coasts of Oregon and Washington in 1887. This plan might be used to advantage along the coast of Alaska or any other section where it is not desirable to wait for the triangulation to be executed. But after the coast triangulation is completed I think the topography should be filled in with the utmost accuracy, especially the shore line, outlying rocks, and the positions of all prominent landmarks and landfalls. As to the accuracy of the contouring a great deal will have to be left to the judgment of the officer in charge of the survey.

We are called on constantly on this coast for the use of our topographical sheets in the location of wharves, landings, chutes, mills, etc., and a great many important land cases have been settled by the use of our topographical surveys of San Francisco and vicinity, our maps being accepted by the courts as correct, and the marsh lines, high and low water lines, creeks, fence lines, and other objects shown on our sheets taken in defining and deciding the boundaries of important land claims. The error in the California and Oregon boundary was discovered by a topographical party.

This is a reputation of which we ought to be justly proud, and it should be our endeavor to keep our finished topography up to the standard.

The cost of topography and the rapidity in its execution depend upon the character of the country and the amount of detail to be put in. Were we called upon to cover large areas of interior topography and do more rapid and less accurate work we might adopt other methods, but at present our work is an accurate survey and too many interests depend upon it to allow it to be otherwise.

I do not believe any of us would care to exchange our reputation for quality for that of quantity, and I think it would be a mistake to permit any departure in our work that would lessen its practical usefulness and value.

LETTER FROM ASSISTANT W. I. VINAL.

In answer to your letter of the 25th inst., I submit the following:

With reference to the first suggestion of the Superintendent, I would say (1) that a good review of the present state of the science and art of topography, with illustrations of the various forms of the plane table, may be found, as you are probably aware, in a pamphlet entitled "The economic use of the Plane table in Topographical Surveying," by Josiah Pierce, jr., of the U. S. Geological Survey.

This paper was read and discussed before the Institution of Civil Engineers of London, England, and was published under its auspices in 1888.

In addition to the purely governmental work, on which it is usually employed, the plane table has been used by the harbor commissioners about Boston, Mass., and in making the detailed surveys of the city of Portland, Me., Fairmount Park, Philadelphia, and elsewhere.

2. The classification of topographical surveys must, in my opinion, necessarily be more or less indefinite. For general purposes the country could be partitioned with reference to its geological structure, but the designation of classes of particular surveys to grades would be largely governed by the peculiar features to be mapped. A convenient method of expressing the character of any piece of work, and therefore its grade, would be to name the scale on which it is required to be surveyed, as 1–10000, etc.

3. The practice of the Coast and Geodetic Survey in the use of contours and symbols for the representation of characteristic features would seem to leave but little to be desired.

4. I believe work could be done more rapidly and with a saving of expense in many cases:

(*a*) By using some other material than backed drawing paper in the field work.

(*b*) By having only the most important features represented on the field sheets by the usual plane-table methods and filling in the survey from records made with a transit and stadia. A small transit fitted with stadia lines and vertical arc can be used with great facility in surveying roads through extensive tracts of wood where great precision of representation and contour are not essential. The use of Porro's telescope, described in Johnson's "Theory and Practice of Surveying," would insure the general accuracy of this class of work.

(*c*) By photography in limited areas when controlled by a number of well located points. Photographs would often be useful, aside from affording material for filling in the map, for they would show the nature of the surface, whether regular or broken, smooth or eroded, and assist in the final representation.

(*d*) In surveys of minor detail the prismatic compass and pedometer may often be found useful. Church's American Pedometer has given good results on comparatively level ground.

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(*e*) The plane table, as now used by this Survey, might be modified so as to admit of adjustment for eccentricity without impairing its stability. The weight of the instrument can also be considerably reduced by using aluminum bronze in constructing the movements. This metal is largely used in the manufacture of instruments and is in many ways preferable to brass.

LETTER FROM SUBASSISTANT FREMONT MORSE.

In response to your communication of January 25, I have but one or two suggestions to offer, and these briefly, since the time limit set for these replies in Washington has already nearly expired.

In regard to the use of contours, it seems to me that the method adopted on some of the recent published sheets of strengthening certain curves (say every 100, when 20-foot contours are shown) should be made general. In rough and precipitous regions it is well-nigh impossible to trace curves on a sheet unless this be done, and I am satisfied that the practice, once adopted on the field sheets, would prevent to a great extent the error of "dropped" curves.

One other point I would advocate in connection with the fourth paragraph of the Superintendent's opening address, and that is the use of the micrometer eyepiece on the alidade in connection with a somewhat longer rod than that now in use, particularly for rapid reconnaissance work. I have had some experience in this class of work, having done all the plane-table work on the reconnaissance of the coast of Washington from Gray's Harbor to Cape Flattery. In this work I used a small table about (as I remember it) 18 by 24 inches, with an alidade correspondingly smaller than an ordinary Coast and Geodetic Survey alidade. It was fitted with a micrometer eyepiece. The rod used was about 10 feet long, with two fixed targets near the ends. At a convenient place, where there was a long stretch of sand beach, a series of observations were made to determine the number of turns of the micrometer corresponding to distances of 100, 200, 300, etc., metres up to 800, and a table was interpolated for intermediate distances. Thus equipped, the micrometer was used to measure the distance along the entire stretch of coast from Point Grenville to Cape Flattery, and I have no hesitation in saying that the work was fully as accurate as it would have been had the distances been measured in shorter lengths with the ordinary rods, and that in point of speed there was no comparison between the two methods. The average length of sight was about 700 metres between stations, and in two or three instances, where shorter sights were not practicable from the rough nature of the shore line, distances of 1 200 and in one case about 1 500 metres were measured.

It will thus be seen what a decided advantage the micrometer alidade has over the ordinary style for this class of work, and I have no doubt that a thorough trial of it in rough and mountainous country, that is not too heavily timbered, will satisfy any topographer of its utility. In smooth and settled country, where there is much detail, it may not be of much use, as in that case the observer must be near the object he is delineating in order to do it intelligently.

LETTER FROM MR. CHARLES JUNKEN, DRAUGHTSMAN.

In answer to the circular letter from the Topographical Conference, I have the honor to submit the following:

I shall not attempt to treat of the first three themes suggested in your letter, but shall confine myself to a brief review of what I consider the best means of securing data for delineating topographical features. As a basis for an extensive topographical survey, I am convinced of the necessity of an accurate system of triangulation as carried on by the Coast and Geodetic Survey as being in the end the most economical.

In which view I am well supported by previous methods and results. I also highly approve of the plan of running lines of levels from well-defined points on the seacoast, extending across the continent, bench-marks being located at convenient points. I am fully aware that the methods above recommended are apparently expensive, but am convinced of their economy in the end, for it is work that has to be repeated that really proves expensive.

For locating the topographic features I most heartily recommend the plane table, as at present used in the Coast and Geodetic Survey. The tachymeter attachment will prove to be of advantage in mountainous districts, where the stadia may also be used. Elevations on prominent points, as usually taken, will prove sufficient for tracing contours.

I do not consider the results obtained by such methods as captive balloons, rough reconnaissance, photographic surveys, and the like, as at all commensurate with the time, trouble, and expense involved.

LETTER FROM MR. A. LINDENKOHL, DRAUGHTSMAN.

In reply to your letter of January 25, inviting me to send to your board any comments I may desire to express, I beg leave to direct your attention to the second part of a report to the Superintendent upon European methods of surveying and map reproduction compared with those practiced by the Coast Survey.

This report is based upon observations which I made at Berlin and at Paris in 1889, during the Exposition, in obedience to instructions of the Superintendent, dated June 17, 1889.

Letters from assistants and others addressed to the chairman of the Conference.

I also send a pamphlet containing a description of a tachymeter (to be returned); can send you one of the Breithaupt plane table, and hold myself in readiness to answer any specific questions you may be pleased to address to me.

U. S. COAST AND GEODETIC SURVEY OFFICE,
Washington, D. C., October 7, 1889.

SIR: In obedience to the instructions of the Superintendent, dated June 17, 1889, I have the honor to submit herewith, in two parts, my official report in reference to cartography, as exhibited at the Paris Exposition of 1889.

By these instructions I was directed to make a thorough examination of the cartographic exhibit, for a twofold purpose. First, I was to render a descriptive report upon the contributions of the several exhibitors, giving statements of the quality as well as quantity of their work; this is treated of in Part I of this report. Secondly, I was directed to examine into the different methods used by the exhibitors for the production and reproduction of maps, and to submit a critical report upon their relative merits in regard to style of execution and the saving of time and expense; this is treated of in Part II of this report.

The time allowed for the preparation of this report precludes any attempt at exhaustiveness, and only such matters have received special attention as were supposed to be of interest to the Coast and Geodetic Survey.

I arrived in Paris July 28, and called on Gen. William B. Franklin, U. S. Commissioner-General, and on Col. Victor Bernard Derrécagaix, Director, etc., presenting such letters, etc., as had been provided me. These gentlemen afforded me every facility, and I beg to express to them, through you, my appreciation of their courtesy and kindness in facilitating the work intrusted to me. I left Paris August 5 and reported for duty at the Office September 2, 1889.

Yours, respectfully,

A. LINDENKOHL.

Prof. T. C. MENDENHALL,
Superintendent U. S. Coast and Geodetic Survey,
Washington, D. C.

PART I.—CARTOGRAPHIC EXHIBIT AT THE PARIS UNIVERSAL EXPOSITION IN 1889.

Cartography and geography are not as completely represented at the Paris Exposition in 1889 as they were at the Centennial Exhibition in Philadelphia in 1876 or at the Geographical Congress in Venice in

1881. The absence of Government exhibits by the greater number of European monarchies at the Paris Exposition has been generally ascribed to political motives, but it may also, in part, be due to economical motives, since these expositions occur at such short intervals and entail so great an expense that many States with slender budgets may not be able to incur it. Under these circumstances it is fortunate for those who went to the Exposition for the purpose of seeing excellent workmanship in cartography rather than to inform themselves upon the actual present state of several European state surveys, for the two European countries, France and Switzerland, that have always been in the lead in what is now considered an absolute necessity, viz, the surveying and mapping of the public domain, make so fine and exhaustive a display there of their public surveys. It is, however, only on rainy days or in the forenoons that these maps can be examined with anything like comfort; in the afternoons of every fine day these rooms are packed by a crowd of people more intensely French in feature and expression than I have ever seen on any previous occasion, not excepting one sunny afternoon at the national gallery at Versailles during the proudest days of the Empire. I should have been inclined to attribute this concourse to a strong development of the taste for fine maps in the French people had this not been contradicted by the circumstances that at the very same time the halls of the exhibit of geography and cosmography, which also contained a fine collection of maps, belonged to the most deserted spots of the entire exhibition. It is undoubtedly patriotic fervor or military spirit which prompts the French to frequent the rooms of the War Department exhibit, and even granted that the more showy display of models of soldiers in all possible uniforms on the same floor with the maps offers the greater attraction, yet there was abundant evidence that the people looked with pride at the achievements of the geographical branch of the military service. A very complete catalogue published by the latter and furnished free of charge, contains a great deal of interesting information about the maps as well as surveying instruments exhibited by the War Department.

Taking up the consideration of the exhibit of charts, etc., by countries, we naturally take first—

France.—The most interesting exhibit of maps, etc., at the whole Exposition is that of the French War Department. The walls of two large rooms are set apart for the display of maps, one room for the modern maps, the other for those of older date. Among the maps of older date a section of a map of *France by Cassini* is the first to attract our attention. It is on a scale of 1–86400, and was the first map in Europe which was based upon geodetic operations. Commenced in 1733, it was not finished until 1815. The topography is represented by long hachures, reaching from the crest of the hills to the base, but without any special attempt at minuteness or reference to steepness of

slope. This map appears again reduced to about one-fourth (1–345600), and is called "Capitaine's map of France (called after its author, Louis Capitaine, who was Cassini's associate and assistant); but here the mountains are represented in oblique light. Noticeable also in this room are the maps of foreign countries made by the French engineer-geographers under Napoleon. Thus we find maps of Italie, Suabia, Bavaria, the country bordering on the Rhine, Egypt, etc., all engraved on copper. The method generally adopted by these "engineer-geographers" for the representation of hills consisted in short hachures along the lines of shortest descent with oblique illumination. The last and finest specimens of these works is the topographical map of Corsica, scale 1–100000, published in 1824. Its realistic effect is truly surprising.

In a room containing the modern maps, two selections of the famous map of France at once engaged our attention; these sections represent the regions of the Alps and of the Pyrenees. This map is engraved on copper on the scale of 1–80000 in 273 sheets. It was undertaken for the purpose of superseding Cassini's, which had been found insufficient. Surveys were commenced in 1818 and continued until 1866. The first sheet was published in 1833 and the last in 1882. This map is universally conceded to be one of the greatest triumphs of cartography; although composed of 273 parts, showing the result of the labor of about 800 men, and engraved by over 65 different artists, it has the appearance of having been done by the same hand. The topography is engraved in such an exact and characteristic manner that the true relief of each section is conveyed almost instantaneously. The same map is reduced to one-fourth (scale 1–320000) in 33 sheets, published between 1852 and 1883, and is now being reduced to scale 1–600000, with parts of adjacent countries (in 6 sheets). All these maps are engraved on copper, the relief represented by vertical hachures corresponding to the inclination of the slope.

The publication of the above three series of maps had not even been finished, when experience taught that they would not answer for all the purposes for which they were intended. For many military, engineering, and internal improvement purposes, the scale 1–80000 was found to be too small. Contour lines were desired as being more useful than hachures, and in consequence of the employment of but one color—black—for hachures and outlines of various kinds, such as roads, rivers, etc., these latter were often so much obscured that they could only be discerned with difficulty by a practiced eye. To overcome these defects, the geographical service of the army has gone to work, without loss of time, to supplement, or supplant, the above maps by others on larger scales, on which different colors are employed and on which hachuring is replaced by contour lines and crayon shading. The new

map of France is on the scale 1–50000 (reduced from the surveys on the scale of 1–40000) in 950 sheets; is engraved on zinc in 6 colors—water *blue*, roads *red*, woods *green*, contour lines *brown*, lettering and inferior roads *black*, tinting *gray*. Contour lines are 10 metres apart. In the same way that the 1–50000 is to supersede the 1–80000 map, another new one on the scale of 1–200000 is to replace the one on scale 1–320000; it will be in 82 sheets, also engraved on zinc for 6 colors, and have 20 metre curves. The illumination for the crayon shading is to be vertical in both series of maps except in the mountainous districts on the smaller scale, where oblique light has been adopted for the steeper slopes in order to save the outlines from being obscured (I suppose on account of better effect too). Finally, a map on the scale of 1–500000, in lieu of the one on 1–600000, in 15 sheets (14 already published). This map, like its predecessor, takes in part of adjacent countries; is lithographed in 5 colors—water *blue*, hachures *brown*, woods *green*, contour lines (100 metres apart) *red*, towns and roads *black*. The relief is engraved in hachures with zenithal light for level and oblique light for mountainous regions.

The War Department has also on exhibition three specimens of the map of Algiers, engraved on zinc in 7 colors, to comprise 327 sheets in all; a map of Mexico, scale 1–3000000, and maps of Tonquin on scale of 1–100000 in 13 sheets and 1–500000 in 3 sheets.

Independent of the maps of France published by the War Department, there is published by the Ministry of the Interior a map of France on the scale of 1–100000, in 590 sheets, in colors—*blue* for water and altitudes, *green* for woods, *red* for principal roads, *gray* tint for the relief (oblique light), *black* for lettering, etc. This map is based upon the map on scale 1–80000, but brought up to date as far as concerns public roads, etc. There is also a map of France by the Ministry of Public Works on the scale 1–200000, in 141 sheets, engraved on copper in three colors (black, blue, and brown). The above review by no means exhausts the list of maps of France published at the expense of the Government; and when it is considered that all these maps are based upon the *état major* survey, which is on the extremely small scale of 1–40000, it must be admitted that Capt. George M. Wheeler, in his report upon the Geographical Congress at Venice, does not exaggerate when he says: "On the whole, it would appear that the Government of France has more map-makers than material for maps."

The French hydrographic service exhibits in two places, in the building of the War Department and in the pavilions devoted to geography and cosmography. The surveys made before 1819 are combined in a portfolio; those of later date are hung up on the wall. Among the latter are those of the coast of Tunis, of Cochin China, the Gulf of Tonquin, the Straits of Magellan, and of French harbors. We had just commenced taking down the titles of these charts (although they can all be found in our office and in the Hydrographic Office of the

Navy) when we were stopped by a soldier on duty, with the remark, "Monsieur, il n'est pas permis de prendre des notes ici." If the guard had been a civilian we might have informed him that we had all these charts at Washington by regular exchange with the French Government.

One of the greatest sights of the Exposition, only excelled by the Eiffel tower, is the immense terrestrial globe by Messrs. T. H. Villard and Ch. Cotard. It is on the scale of 1–1000000; the diameter measures 12·732 metres and the circumference 40 metres. A conception of its size may be formed by a comparison with some well-known published charts. Thus, it takes two huge sailing charts on even a smaller scale (1–1200000) to delineate the Atlantic coast of the United States from Maine to Florida. The largest and best general atlases do not reach this large scale, even for the most minutely drafted countries. Thus it takes four sheets on scale of 1–1500000 in Stieler's Atlas to show the whole of France, and the same number of sheets on the same scale for Germany. The globe, however, is not intended to be subjected to very close inspection, and although its general accuracy is to be highly commended, the outlines of the continents and their features are greatly generalized. The mountain chains and the bed of the ocean are not shown in relief, but by colors, because the highest mountains, taking them at 8 000 metres, would appear at an elevation of but 8 millimetres, a dimension which would be scarcely appreciable. It can not be asserted that the construction of this globe solves any geographic problem or advances geographical science, but it certainly is an interesting object to all who take interest in geography, regardless of proficiency.

In the pavilion set apart for "geography and cosmography" there is a large collection of geographical maps, atlases, relief charts and globes, all by French authors, and made at Paris. Among the maps and charts there are many that have no special merit. It is too often plainly visible that the authors themselves were not intimately acquainted with their subject, and the style of execution, as a rule, is inferior to the better class of corresponding German works. Under these circumstances it was an agreeable surprise to find in the examples of the Universal Atlas, by Vivien de Saint-Martin and F. Schrader, published by Hachette & Co., a quality of work that rivals the best productions of England and Germany—the Imperial Atlas, by Keith Johnstone, and Stieler's Atlas, for instance. Their accuracy is unimpeachable, the selection of names shows excellent judgment, and I was especially struck by the beauty of the hachuring, which is very clear, and at the same time sufficiently mellow to leave to outlines and lettering due prominence.

In the matter of relief charts the French certainly evince a great

deal of enterprise and skill, and greatly surpass the Germans. Too much space would be required to mention all the fine models exhibited, but a few may be noticed of special scientific interest. The Alpine Club had a model of Mont Blanc, by Bardin, and one of Mount Perdu (Pyrenees), by F. Schrader; but the pearl of all was a relief chart of France, extending from Paris and Lyons to the Mediterranean, by M'elle C. Kleinhaus. This, I believe, is the relief constructed under Levasseur's direction, and which attracted so much attention at Paris in 1875 and at Venice in 1881.

Switzerland.—Next to France, Switzerland makes the greatest display of maps. There is the celebrated Dufour atlas (1842–'64), scale 1–100000, in 25 sheets, engraved on copper. It is shown in atlas form and twice as a wall map; one a geological map and the other retouched with the brush to heighten effects. The latter especially rivets our attention by its surprising plastic effects. The Dufour map has, since its appearance, been considered one of the greatest masterpieces of cartographic art; its peculiar feature is the selection of oblique light for the steep slopes, as on the backbone of the Alps, and vertical light for the rest of the map, and it is generally admitted that no other method could have been equally effective in bringing out the relief of the *terrain.* There is also shown a reduction of this map to 1–250000, in 4 sheets. It would appear that Switzerland had very much the same experience with these maps on 1–100000 that France had with her 1–80000 map, to wit, that it would not suffice for all practical purposes on account of its small scale and the absence of contour lines. The last sheet of this atlas had scarcely reached the public when the Confederation set about publishing the plane-table sheets on their full scale, which is 1–25000, with contour lines 10 metres apart for the more level regions, and 1–50000, with 30-metre-contour lines for the mountainous regions; the former to be engraved on copper and the latter to be lithographed, and the whole series to comprise 561 sheets, of which about 400 have been published to date. Inasmuch as this atlas is constructed on a different method from the French atlas on the same scale and is rated in Europe as one of the best models for topographical representation, it may be well to indicate the manner in which the three colors in which it is printed have been applied.

Black is used for lettering, buildings, roads, forests, for contour lines where the ground is bare of soil and vegetation, and also to hachure steep slopes and steep rocks in oblique illumination; *brown* is used for contour lines and hachures of inferior slopes in vertical light; *blue* for water and contour lines on glaciers. However effective this method has proved in the hands of the Swiss for the representation of the Alps, the delineation of flat countries, like Denmark, by contours only, without shading or hachures, has been found to destroy all natural effect. No method of representing the relief by contour lines has yet been devised which meets universal approval. The Swiss also exhibit sev-

eral fine models, and in their attention to this particular method of geographical and topographical representation seem to be, with the French, ahead of all other nations. S. Simon and X. Kufeld have reliefs of the Four Cantons, Mount Rose, and the Jungfrau.

The only other European countries which have official maps on exhibition are Servia, with sections of a map of the state on scale 1–75000 (that of the Austrian atlas), by its major-general, photolithographed in colors, contours *sepia*, woods *green*, principal roads *red;* tolerably good. Russia only shows a model of the Caucasus. The Republic of San Marino has a good MS. map, scale 1–10000, with contour lines 10 metres apart. The Grand Duchy of Luxemburg contributes a good topographical map on scale of 1–40000, which also is made the base of several special exhibits, such as geology, forestry, telephone service, railroads, and archæology.

The excellent lithographed maps of Holland (scale 1–50000 and 1–25000) were not exhibited, but there were several river and harbor charts in the Dutch section, showing proposed improvements.

Whatever may have been the motive of European governments in withholding their national surveys from the Paris Exhibition, this policy does not seem to have been applied to the surveys of their colonies.

Holland has a fine atlas of her East India possessions in 14 sheets, with special maps of Java and Sumatra. As far as regards England, though neither the Ordnance Survey nor the Admiralty Charts were to be seen, there were very numerous, partly official, maps and charts of the different colonies, especially of New Zealand and Australia.

Mexico makes but a small exhibition of maps, though she has undoubtedly taken great pride in her proper representation in other respects. There is but one section exhibited of the "Carta de la República Mexicano," by the "Comision Geográfico," under the Secretary of War (contour lines with oblique shading), and I could not ascertain if there were any more in existence. The general map of Mexico (scale 1–2000000), although bearing the date 1887, did not expecially recommend itself. I have seen much better maps of Mexico elsewhere.

The *Hawaiian Islands* have a general map, "based on government surveys," by S. G. Bishop, 1886, and special maps of several islands by W. D. Alexander, Surveyor-general of the Hawaiian Government survey.

Japan makes a very creditable show. There are exhibited, besides numerous geological and meteorological charts, the following maps as the result of her geological survey, commenced in 1880: Two reconnaissance maps, scale 1–400000, and 12 topographical sectional maps with horizontal contour lines, engraved in Tokio. It is to be noticed that Japan is following an American custom. Like our U. S. Geological Survey and

many of the State geological surveys, it is publishing principally and primarily topographical and geographical maps for the well-known reason that geological surveys without good topographical and geographical surveys and maps as a basis can not be of permanent value.

The above list is believed to complete the review of countries which exhibited the results of regularly organized government surveys. On the part of *Brazil* and many of the *Central* and *South American Republics* there does not appear to be a desire manifested to shroud their geography, but rather the contrary, a desire to bring it into the most favorable light, and several of these countries have engaged the services of eminent French artists (engineer geographers, as they call themselves), members of the Geographical Institute of Paris, to paint the walls of their palaces with maps of their respective countries, showing at a glance its geographical position, its shape, and general features. *Brazil*, *Chile* (also with 3 historical maps), *Venezuela*, *Bolivia*, *Nicaragua*, and *Honduras* are shown in this way. The *Argentine Republic* has adopted a method of introducing herself to public notice which is more novel than and quite as effective as that adopted by her sister Republics, by exhibiting a huge model made as a spherical segment on a scale of 1–500000 (vertical scale 1–100000), based upon the geological examination of Drs. Burmeister, Brackebush, and other explorers.

The *United States*, in their cartographical exhibit, occupy a position of neutrality between monarchical Europe and republican America. They have sent their maps to Paris, but do not appear to be over anxious to attract attention. After having repeatedly looked all over the space allotted to the United States, and inquiring from attendant to attendant I did not succeed in finding a single Coast Survey chart, nor a map of the Geological Survey or U. S. Engineer map, until I engaged the attention of one of the assistant commissioners, who showed me a case in a hidden recess, which he assured me was filled with such maps, but which in no possible way could have been spread out for the want of space.

Models of proposed canals may not strictly have been included in the line of inquiry, but since they furnish such an attractive feature to the Exposition it may be as well to state that the beautiful Menocal model of the projected Nicaragua Canal, which was on exhibition here in Washington about the time it left the artist's hands, was in successful operation, as also were two models of the Suez Canal, one for daylight and the other showing it illuminated by light-houses for navigation in the night. The official guide books had also provided for a model of the Panama Canal, but it could nowhere be found.

All the South American Republics were represented at the Paris Exposition, and those which had neither models nor maps frescoed on the walls had at least a general map suspended, but not always of the best types.

Uruguay had two maps; one by Don F. A. Berra, 1882, and another by Angel Carlos Maggiolo.

Letters from assistants and others, addressed to the chairman of the Conference.

Salvador, a map "political, escolar, and telegraphic," by G. J. Dawson, engraved in Paris, 1887.

The *Republic of Colombia* had official maps of the whole state and of the separate provinces, by Manual Ponce de Leon, 1864.

Paraguay had a map without giving the author or date.

Lastly, *Transvaal* (South African Republic) had a map by Fred. Jeppe, 1889.

Part II.—On the Different Methods used in the Publication or Reproduction of Maps and Charts.

Before entering upon the subject of different methods used in cartography, it seems proper to notice as germane to the matter some differences between the methods and customs followed in making topographic surveys by the U. S. Coast and Geodetic Survey on the one hand and European governments on the other.

Linear measure.—In making surveys, it is the custom in the Coast Survey to make use of the French metre for horizontal distances and of the foot for vertical distances. The necessity of a constant resort to two standards which are not commensurable is not a mere inconvenience, but an actual impediment, detracting from the accuracy and rapidity of the work. It would nowhere else be tolerated. Since it is not to be expected, however, that, after having used the metre since 1817 for all our geodetic work, we shall now go back to the yard at a time when all European governments, with the sole exception of England, have either introduced the metre or are perfecting measures to that end, it is to be hoped that at some not very distant day the metre will not only be used for horizontal measurement, but also for that of the height of the land and the depth of the sea. Such is now generally the practice in Europe; in the flat countries contour lines are given at intervals of 5 and 10 metres, and in the mountainous countries, like Switzerland and Norway, at intervals of 10 and 30 metres.

Plane of reference.—In the Coast Survey it is the custom to take the high-water line as the datum level, and to determine height by the plane table by vertical angles. In Europe all heights are referred to the mean level of the sea, and no plane-table survey is undertaken unless a sufficient number of bench marks has been determined by a system of precise leveling. It would probably be considered injudicious to make a change in our rules at this time when our survey is nearly completed, but our experience in executing work for special engineering purposes is such as to warrant the belief that in the future, in all work of a critical nature where a fraction of a foot is a consideration, and for all work which shall rigorously comply with the highest scientific requirements, the effects of the tide will have to be eliminated

from the levels, and the sensitive spirit level be substituted for the alidade.

Scale of plane-table sheets.—The experience of the Coast Survey through a long series of years teaches us that the adopted scales for topographic surveys, viz: 1–10000 for densely populated districts or intricate work, and one 1–20000 for sparsely inhabited and less valuable sections of country, are the very best which can be devised. In the face of this experience it is rather surprising to find the majority of European countries using the very small and rather odd scale of 1–25000 for their plane-table surveys. The explanation is to be found in two circumstances, the first of which relates to the scale of publication generally either 1–50000 or 1–100000. The scale of 1–25000 is preferred to that of 1–20000 because much stress is laid upon a simple ratio, one-half or one-fourth being considered more intelligible than one-fifth or two-fifths. The other reason for the retention of the scale is to be found in the diminutive size of the European plane-table sheet; it averages about 17 by 20 inches, while in the Coast Survey sheets 30 by 52 are worked on with the greatest facility. The desire to keep the number of plane-table sheets within reasonable limits may also prompt the adoption of this otherwise inconvenient scale. It takes 5 206 plane-table sheets for the survey of the German Empire alone. If the scale were to be increased from 1–25000 to 1–20000 the number of sheets would be swelled to over 8 000.

Scale of publication.—The European governments do not appear to have arrived at any agreement for uniformity in the scale of publication of their topographical surveys. England adheres to 1–63360 for her general maps; France has adopted 1–50000 for her new map in place of 1–80000; Germany and Switzerland prefer 1–80000, and Austria 1–75000. For the coast of the United States the scale of 1–80000 was selected very probably for the reason that at the time the selection was made the map of France was the only national publication in Europe of sufficient merit to be taken as a model. However, our experience with this scale has not been unlike that of France, as it has been found too small for the preservation of all the detail of the survey and for many practical purposes. Thus the whole of the coast of Maine had to be reproduced on the scale of 1–40000, and there are harbor charts published on a great variety of scales from 1–5000 to 1–60000. While the diversity of scales can not well be avoided, it would be well to follow European custom by abolishing such scales as 1–50000 and 1–60000, and to confine ourselves to the use of simple ratios, say, 1–40000, 1–20000, 1–10000, etc.

METHODS OF PRODUCTION AND REPRODUCTION OF MAPS.

In taking up the subject of methods of map production in connection with the Paris Exposition, it may be just as well to set at rest the question that has been put and answered a hundred times, but is sure

Letters from assistants and others, addressed to the chairman of the Conference.

to come up again. The essence of this question may be stated in these words, "What is the use of going to an exposition to look at maps that you can see at home in your library?" When you look at a map in a library it occupies the position of a client, and you can not entirely free yourself from the prejudice, but when you look at the same map in an exhibition you divest yourself of your individual opinion, you act as an umpire and reflect the general opinion. A good map never appears to better advantage than when on exhibition, and a poor map never looks worse than when in contrast with better ones. It may also be stated at once that some of the modern processes of map-making did not have their proper exponents at the Exposition, and therefore much information had to be sought for elsewhere.

Copper engraving.—With all the great advances that have been made within the last few decades in the method of producing maps, the fact stands out patent that nothing has yet been devised that will equal a good copper-plate engraving. For this reason the most respectable establishments go on, as heretofore, and have their best maps engraved on copper, and although a great deal is said about the scarcity of engravers, I have not learned that either the British Admiralty or the U. S. Coast and Geodetic Survey, both of which carry on very extensive operations of this kind, have been seriously embarrassed on this score. The cost of the material need not be taken into consideration at this time, when copper is so cheap as to be substituted to a large extent for iron and tin for common building purposes. The advantages of copper engraving, besides the superior elegance, are its durability and the facility with which corrections and duplicates may be made, and its only serious disadvantage is the greater expense of printing.

Heliogravure.—When the Austrian Government, in 1875, emerged from the field of experiment and commenced the publication of its atlas of 720 sheets by heliogravure instead of by hand engraving, an undertaking which I believe has since been carried to a successful conclusion, not a few people were of the opinion that, on account of its great saving in time and money, it would in a great measure supersede the old-fashioned style of hand engraving. The late Dr. A. Petermann, as appears by a contribution to his Geogr. Mittheilungen, written shortly before his death,* seems especially to have taken quite an enthusiastic view of the future of heliography, but we find after a lapse of over ten years that it has not made much headway. The Prussian Government, after making some experiments, wisely determined to go on with hand engraving, and even at Gotha I could not learn that any of the engravers had been pensioned and draughtsmen substituted for them,

*See Petermann's Geogr. Mittheilungen, 1878, pp. 205 to 210.

and Steiler's Atlas is still engraved on copper, as heretofore. The fact appears to be that the Austrian Government took to heliogravure more from necessity than from choice; it had allowed copper engraving to fall into decadence, instead of nursing it, and in its stead raised an excellent corps of topographical draughtsmen. Dr. Petermann estimated the relative expense of engraving and heliogravure as 4 to 1, and I do not think that he exaggerated the difference, but what could be done in Austria may not be done as well elsewhere. Where will you get the requisite number of draughtsmen who can draw as sharply as an engraving and will not require at least as good pay as an engraver? And what if they spoil the job, not to mention all the uncertainties of chemical and optical action? The great defects of heliogravure are common to all patent processes intended as substitutes for engraving. Drawing never is equal to an engraving, and the heliogravure of a drawing never excels and rarely equals the original. The great trouble is with the faint lines, which will not come up as well as the heavy ones, and for this reason, even in Austria, all outlines, water lines, and straight lines are cut in by hand.

Zinc engraving.—About the only advantage zinc has over copper for engraving purposes is its greater cheapness. In every other respect it is inferior. Its texture is crystalline, it is brittle, and for this reason it will never be a favorite with the engraver, who calls it a rotten metal, and will charge more for work on it than on copper. At the French War Department the new map of France, on scale of 1–50000, is engraved on zinc for six colors on 950 sheets, which alone requires 5 700 plates. In order to insure the proper registering of the six plates for each sheet, all the outlines, except the contour lines, whether intended to be *black*, *blue*, *green*, or *red*, are engraven on one zinc plate and transferred to the respective color plates by dry prints. The engraving appears to be quite well done, but this is no reason why zinc engraving should be recommended to other establishments. The French have their engravers trained to the metal; the work is exceedingly plain, and its only advantage is the greater cheapness of zinc compared with copper, while it has the disadvantage that it can not be manipulated as well by the engraver, and that corrections can not be made as easily and repeatedly as on copper.

Lithography.—Since the advent of photolithography the lithographing of maps has greatly fallen into disuse, and the only reason that it is still carried on to some extent in Europe, notably in the reproduction of the plane-table sheets of the Swiss and Prussian surveys, is the fact that there are an abundance of good lithographers at hand and a corresponding want of equally good draughtsmen; and, furthermore, the objection that these governments do not wish to change the plans of great national undertakings while under progress of successful execution.

The reason why the lithographing of maps is still persevered in by

some private establishments is the fact that much lithographing is done for commercial purposes, blanks, bill-heads, etc., and the engravers may better devote their spare time to map-engraving than to idleness. The great objection to lithography for map-engraving is its perishable nature and the difficulty of making corrections. Although it is not a subject of emulation, it is a fact that some of the finest atlases, like those of the Netherlands, have been engraved on stone, and it will forever remain a subject of great regret to the enthusiast in cartography that such a fine monument of a model topographical survey as that of the former electorate of Hesse-Cassel should have been engraved on stone instead of on copper. Even if it should be possible to preserve these stones in good condition for an infinite time, they are too cumbersome and expensive to warrant the experiment.

Photolithography.—The introduction of photolithography, about twenty years ago, for the reproduction of maps, has wrought quite a revolution in the practice of cartography. The possibility of having it in one's power to have any map, in fact any drawing, reproduced in any desirable number of prints, or any desired scale, nearly equal to the original, at the shortest notice and at small expense, is the great achievement of photolithography. At the time when nearly all cheap maps were lithographed, the drawings were hardly ever made with the finish which they were expected to receive from the hands of the engraver, and, as a consequence, too much was generally left to the judgment of the engraver, and errors crept in which it was difficult to correct upon the stone. Now, with photolithography the mental work is all done by the draughtsmen, as it should be, and the mechanical part only by the artist. Another great advantage of photolithography lies in the fact that the originals can be kept without expense and be corrected and reprinted whenever required. Some of our progress sketches have in this way been corrected and reprinted for more than ten consecutive years without any injury to the drawings. A stone would not bear such repeated corrections, and would represent a dead capital whenever not in actual use. It must not, however, be supposed that photolithographing maps is an easy matter. In order to obtain the proper scale and dimensions, and to get the photograph properly developed, a fine apparatus, great skill and experience are required; all matters in which different methods and practices, usually regarded as secrets of trade, prevail. There are a number of establishments in this country, that are not surpassed by those abroad, which pay especial attention to the photolithographing of maps, and give the greatest satisfaction to the several branches of the Government from which they find extensive employment.

Transfers on stone and zinc.—Whenever large editions of a map are required and great delicacy is not a consideration, it has been the cus-

tom, in order to save time and expense, to print copper and stone engravings from transfers on stone. The French print their new map of France in six colors and their map of Algiers in seven colors, engraved on zinc and from transfers on zinc. The French appear to be altogether inclined to do too much cheap printing from zinc transfers. While they even place in the market cheap zinc transfer prints of their fine map of France, engraved on copper, the German Government only sells proofs from type plates. When it is taken into consideration that to have the new map of France always ready for the printer would require 5 700 separate stones, which would not only represent a very respectable investment, but would also demand a very large storeroom and prove a most unwieldy mass of material, we can appreciate the good judgment of the French in substituting zinc plates, all of which can be encompassed in a closet of moderate dimensions, always ready and convenient for use. A great deal may be said against the employment of many colors, and the French may be said to have quite reached the limit of artistic propriety and to have gone more than half way to meet popular indolence. The employment of three colors—black, blue, and brown or red—may be considered quite sufficient to facilitate the reading of a map; still, the same objection against the use of stones for printing even with the few colors holds good, and it is rather a matter of surprise that the French have no followers in this practice. As long as our Government has no establishment of its own for printing by transfer, it can only be a matter of indifference whether this printing is done from stone or zinc if it is properly served by private firms. Some private firms do a good deal of cheap printing from zinc plates, especially crayon work, but are disposed to speak disparagingly of the use of zinc for map-printing. There may be some prejudice against the employment of zinc by lithographic printers on financial grounds, by reason of a large capital invested in stones, yet it remains true that transfers on stone are finer and in every way superior to those on zinc for maps and line work, because the zinc, for the manipulation, requires a grain which, however fine, interferes with the sharpness of the lines. The difficulty or impossibility of making correction on transfers on zinc also operates against its employment for maps or chart printing. There may be emergencies, such as happen in times of war, when it is desired to obtain the greatest possible number of prints at the shortest notice and when the compliance with specifications by which time is lost is suspended; those would appear to be the occasions when printing from zinc transfer would be in order.

It may be mentioned in this connection that the U. S. Geological Survey had the subject of zincography, as practiced by the French War Department, brought to its attention, but after carefully investigating the subject in all its bearings, concluded to defer action and go on in the old style of engraving on copper for three colors and printing by contract from transfers to stone.

No special reference is made to the process of photozincography as

Letters from assistants and others addressed to the chairman of the Conference.

practiced by the English Ordnance Office, because it is only applied in the production of parish plans on the very large scale of 1–2500. Nor shall I attempt any description of the several processes of photogravure, zincography, and photolithography, as practiced at Vienna, Paris, and Southampton, because such descriptions by a nonprofessional do not amount to much, and no secret is made of their methods by the several governments and all desirable information is always cheerfully furnished.

After a review of the principal methods of producing and multiplying maps I arrive at the conclusion that about the same condition of things exists therein as in surveying, where there is no such thing known as a universal instrument, or one that would serve all purposes equally well, but where, under certain conditions and for certain purposes, there is always some particular instrument or some instrument of peculiar construction, which deserves preference. In a similar way I find that there is no one method of map production that could be recommended for general adoption, but that each method has its merits and defects.

LETTER FROM MR. F. C. DONN, DRAUGHTSMAN.

Your letter of January 25 has been received with inclosed copy of memorandum of the Superintendent's suggestions, and invitation to send to your Conference, in writing, any comments thereon that may seem appropriate.

Thanking the Conference for the courtesy so extended, I beg leave to say, that having been out of the field since 1878, excepting several short intervals, I have not informed myself concerning improvements in instruments and methods of work.

Principally occupied in hydrographic draughting, but few topographical sheets have been examined or studied. Those which have come under my notice, however, have convinced me that a number of improvements might be made by the topographer in the direction of conventional signs. Of course the topographer who makes the survey and inks his own sheets has no difficulty in the matter, as every feature will be present in his mind, but when it is remembered that few draughtsmen are topographers, I think every detail of the work should be so represented when the sheet is finished that any draughtsman would be able to make a copy with absolute certainty as to the meaning intended.

I will state briefly some of the difficulties experienced.

High-water lines should be continuous, but in some cases they are lost or covered up by other features. These lines should be the most prominent feature of a sheet and their position never doubtful.

The line separating the highland from the marsh is variously represented by a continuous line, a dotted line, or by a continuous line with short hachures at right angles to it, by lone hachures or ends of the parallel lines significant of marsh areas. The continuous line is often mistaken for that of high water, especially when creeks intersect the marsh. This making of marsh boundaries should be represented in such manner as would prevent the possibility of mistaking them for the shore or high-water line.

Salt and fresh water marshes in many cases can not be distinguished apart.

Contours cause a great deal of trouble because too few heights are given. In the case of bluffs or steep slopes when the curves merge into them, it is difficult to fix the heights of the crests. In minus curves or curves of depression the conventional sign is very frequently omitted. The elevation of such D curves should be indicated to prevent the possibility of confusion or uncertainty.

These instances are taken from practical knowledge of the difficulties under which draughtsmen labor; the sheets containing them are of recent surveys.

These points may have already been brought to the notice of the Conference, and if so, one more witness from the draughtsman's side may give emphasis to the matter.

If I may be permitted to make a suggestion, I will say that the office will be more efficiently served if each topographical draughtsman could have a season or two in the field work in sections which afforded him the largest opportunity to study characteristic features, under the direction of some skillful topographer of the Survey.

SUPPLEMENT B.

THE TOPOGRAPHY OF THE COAST AND GEODETIC SURVEY, WITH RELATION TO ITS DEVELOPMENT AND FURTHER POSSIBLE DIFFERENTIATION, WITH A CONTRIBUTION THERETO OF A DESCRIPTION OF A PRACTICABLE METHOD OF BALLOON SURVEYING.

[By Assistant R. M. Bache.]

The topic which I here beg leave to present to my fellow members of this Conference, and crave for it their careful consideration, is that of topography, regarded in its broadest and also in some of its minutest aspects, beginning with its evolution on the Coast Survey. In attempting to present you with this view of inception, progress, and final accomplishment, I bring to bear an experience since my boyhood, which experience necessarily includes that of others as well as my own, digested finally in my mind, all bound up in clear recollection of the phases through which observation of others and personal effort have brought to me firm conviction upon the points upon which I purpose to enlarge.

Inasmuch as the development of accurate and elaborate topography is a product almost confined within the present century, it will not be necessary, in the customary way of exhaustive discussions of a subject, to go back to the flood, when the dove, as assistant topographer, brought in a sketch of the condition of the earth's surface, followed soon by Noah's first survey of the summit of Mount Ararat.

Referring simply to this country, where elaborate topographical methods and performance, partly of native and partly of foreign inception, have reached so high a degree of excellence as at present, not excelled at any time abroad, and that within so limited a period as within the century, I would first of all call attention to the circumstance of evolution everywhere of extended, fine topography being almost confined within that limited period. Naturally it had to wait for geodetic triangulation. Next, it is to be particularly noted that the first piece of extended, accurate, and elaborate topography in this country was that executed by my father, Capt. Hartman Bache, then of the Topographical Engineers, U. S. A., between the years 1821–'25, several years before the Coast Survey was in effective operation. Comparatively crude as it was in graphical presentation, as compared with later similar work, for at that time conventional signs were very unsettled, the map which was the product of that survey, taking in Charleston harbor and city, South Carolina, including hydrography as

well as topography, and extending inland much beyond the future work of the Coast Survey, was accurate to a degree seldom equaled and never excelled for its scale, as in the course of Coast Survey work I subsequently had the means of ascertaining, and as was similarly testified to by Army and Navy officers during the war, when they had occasion repeatedly to refer to the work in connection with military operations near Charleston.

Some twenty-five years after the execution of this work, when, as a mere boy, with scarcely any experience of topography, I was present at a conversation between Capt. (then Major) Bache, and our chairman, Mr. Whiting, then my chief, who, young as he was, was in proficiency even then the Nestor of topography on the Coast Survey, I heard on the one hand the latter speak in the most complimentary terms of the excellence of that Charleston survey, and the former, on the other hand, deplore that at the period concerned he had not had the facility for topographical work that the plane-table affords.

I do not intend to imply by what has been said that this Charleston work was executed single-handed by Capt. Hartman Bache. On the contrary, as I am speaking to the point, first of all, of the evolution of topography in this country, I wish it to be clearly understood that he had as assistants with him several officers; for the operations of the Topographical Engineers then, like those of the Engineers now, and always, were conducted on a generous scale of life for educated men. The junior officers, as assistant topographers, were Lieuts. James D. Graham, C. M. Eakin, and W. M. Boyce, all belonging to the Topographical Engineers. They were well grounded in the principles of accurate work, and Eakin, who with Boyce afterwards went on the Coast Survey, was a born topographer, for the topographer, like the poet, is, as you know, practice in his art aside, born, not made. Eakin coming, through his advent upon the Coast Survey, upon its accepted topographical instrument, the plane-table, did not for the future labor under the disadvantage which Maj. Bache had regretted in his own behalf. He did admirable work with that instrument, and being well instructed in its employment, his pupil, our present chairman, took a much higher flight than he in excellence, producing, with his singular aptitude for the plane-table and topography, maps that, within their individual scales, never can be excelled in effective graphical delineation of ground.

In what I have said there is no disparagement of the foreign topographers who came in with Mr. Hassler as Superintendent of the Survey. They worked according to the general requirements of a period when funds were lacking and large areas had to be hastily covered to make a show of production, upon which the very life of the Survey hung. The standard of accuracy, moreover, even among surveyors and engineers, was then much lower than at present. They worked up to the general requirements of their day; few men ever do more. The particular set of men who did more than that I have mentioned,

and my conviction, from having in the field touched upon the earliest work of both native and foreign topographers in this country, is that the palm of excellence is due to the former for accuracy and elegance in topography, finally permeating the whole of that sphere on the Coast Survey, and that, foremost of the men to whom that result is due, and without whose impress it is questionable if the topography of to-day would stand as high as it does, was our honored chairman, Henry L. Whiting.

It follows, as a legitimate inference from the point upon which I first of all dilated, that I deem the modernized plane-table the best topographical instrument extant. I say more, that it is the best topographical instrument possible, for the simple reason that it combines the office with the field; that whereas the field-transit entails the maximum of elaborate notes, and the maximum of precise sketching, and not only renders it possible and certain that discrepancies will manifest themselves eventually in plotting, even when the greatest care has been taken in the field, and also that, to obtain final results, there must be a great expenditure of time, its final product for elaborate surveys (and we are supposed to be speaking only of those at present) is, as compared with that of the plane table, at best bald and skeleton-like, unless play be given to the imagination, which should have no part in topographical delineation, save in the acceptance and artistic treatment of conventional signs.

It follows, if what I have asserted of the plane-table as compared with other topographical instruments be true, that its performance in given hands is the most crucial test of the expertness of a topographer. Every case in topography is, as you know, a special case, from the determination of the individual station, through the details that shall be obtained from a particular station, through the whole succession of stations which in sum produce a survey; which include in their entirety the best mode, in generals and particulars, of attacking the ground. Back of the choice of a particular instrument for topography lies for good work the determination of the question of the scale to be adopted for a certain map, a question too often neglected. It should, nevertheless, be obvious that the scale to be adopted is properly determinable only upon the basis of the previously settled question as to the exact purpose of the survey. It is as preposterous to adopt a scale too large for the precision and elaboration to be devoted to a map, as it is to adopt one too small for the precision and elaboration desirable. In any event, however, whether the scale be well or ill chosen for a given purpose, the plane table remains paramount as the instrument of instruments for topography on any scale.

But in saying this I do not mean to imply that the plane-table may not employ useful accessories, however skillfully it may be managed. Although it is, in its modernized form, virtually perfect for its purpose,

I can not but think that some useful accessories to it have not been sufficiently employed. In its capacity, through easy angling upon or telemetering to subsidiary objects, to determine them, nothing can be conceived as affording greater facilities for all horizontal work. To some degree, through the arc of its alidade, by means of which we can, for moderate scales and over small regions, obtain elevations with sufficient accuracy, it compasses the determination of heights, and to some degree also it may be used, through its modernized alidade, as a leveling instrument, although that method of leveling, involving the use of the whole heavy instrument, does not in practice lend itself favorably to the execution of extended leveling. I was therefore driven, early in my experience on the Survey, believing, as I did, that our vertical work in topography was unduly below in accuracy the standard of our horizontal work, to employ special leveling instruments of a greater or less degree of precision, as the case might seem to require. About 1853 I exhibited to Prof. A D. Bache a hand level (Locke's) which I had used for a short time, in whose working he took great interest, trying it with me out of a hotel window in Savannah, Ga. Contemptible as the instrument is as one of precision, it yet serves admirably as an accessory to plane-table work in a hilly country, and at any rate, I judge, from the evident ignorance at that time of Prof. Bache about the instrument, that I had the honor, such as it is, of introducing it upon the Survey, where it has proved useful, and indeed sometimes, in careful hands, performs beyond what one might expect of it, as Prof. James D. Dana once proved to me, by showing me the results of a line of levels which he had run with it between points of which I had obtained the elevation by regular spirit-level determination.

The measure which I should like to see adopted for fine vertical work in hilly country, in conjunction with scales not exceeding 1–5000, would be the general introduction of the spirit level for the production of critical points of precision at, say, the moderate limits of half a mile apart, over the whole area, and of the *niveau d'eau*, the French water level, wherever desirable within those limits. Just as our delineation of all horizontal features of a country depends primarily upon the establishment of critical points, supplemented when required by tangents, so the vertical delineation of the same country should be made commensurate in accuracy with its horizontal delineation, by means of the establishment of critical points of reference for elevation. My method of accomplishing this to the best advantage, in a case which required special precision, although the scale was only 1–10000 (for the survey was for minute geological purposes), was by running some approximately parallel lines of spirit leveling through a nearly square area of about 100 square miles, tying on, where facility offered, intermediately to their termini, and then supplementing with other levels within the areas circumscribed, by means of the *niveau d'eau*,

The topography of the Survey with relation to its development, etc.

which I have had constructed with simple gas pipe and elbows, the whole instrument with its tripod not weighing over 5 pounds. With this rapidly-working instrument one can run a mile of levels with a probable error not greater than two or three-tenths of a foot, far within any necessity of scale. Within four years an official of St. Louis, Mo, who was my assistant there during the war, when I made a survey from St. Louis to Carondelet several miles below on the Mississippi, wrote me that the aforesaid work remained to that day the best authority that the city possessed, whereas the work above it, with which mine joined, executed without any system of leveling, was entirely worthless to the city. Yet the *niveau d'eau* was the sole leveling instrument used, carrying elevations accurately over several miles.

There is another instrument, useful as an accessory to plane-table work, which I should not omit to mention because it happens to be of my own invention. This is merely a telemeter, reënforced on its back by a strip of wood, to stiffen it, and supported on a vertical stanchion, from which it is detachable, and on which it can be revolved by the sketcher in the bow of a boat. It is graduated to 5 metres, and can be read intermediately to 1, for a distance of 300 metres, or, of course, by doubling up, to a distance of 600. For all calm waters, with margins upon which it is impracticable to stand, for all shores covered with high reeds, nothing can take its place. When I look back to the time lost in former years in placing tags on withes, and then determining their position, under the difficulties sometimes of special stations for the purpose, the facility with which I have long been able in such places, with the assistance of a good sketcher, to sweep in a large area with perfect accuracy has been quite delightful. In such places the expenditure of time and trouble, as experienced in the general method of obtaining them, is reduced by comparison to nothing.

Speaking of material things as useful accessories to plane-table work should not lead to forgetting that the service of at least one good sketcher, preferably two, is a most useful adjunct to the work of the chief of a topographical party, whose general presence at the instrument, as the focus of operations, is indispensable to the execution of the most rapid, consistently with its being the best work. This class of men has not been sufficiently fostered on the Survey. Represented by individuals who assist like "hands," carrying, pulling an oar, etc., it only needs that their moderate pay be made continuous, and that they be transported from place to place, to secure a class of men as a part of the personnel of the Survey, that would add immensely to the relief of chiefs of topographical parties and prove of advantage in the economical production of work.

I mentally admit in my scheme for improving the art of topography the largest range in actual practice. I begin always, as I have said,

with the question of the purpose of the particular survey in contemplation, upon which depends, as I have also said, the determination of the scale which should be adopted. Upon the scale adopted for it, in turn, should depend the greater or less attempted elaboration of both horizontal and vertical work. A map may legitimately be on a scale so small as to preclude detail to a degree that necessarily makes of it a sketch in character, but one can not legitimately be on a scale so large, with reference to actual elaboration, as to profess, while in fact virtually a sketch, to be accurate and comprehensive up to the capacity of its scale; and yet that is exactly what every large scale map, without corresponding accuracy and fullness, and without qualifying notes, falsely professes to be. In a word, the being in fact that which a map on its face professes to be, is indispensable truthfulness in topography, in every delineation of the earth's surface, from geographical maps down to and through every phase of topographical representation.

In saying, as I do, that the sole condition of the truthfulness of a map is that it shall be that which on its face it pretends to be, is necessarily involved the admission that maps may legitimately have, dependent upon their purpose, and therefore, as should follow, upon their scale, various degrees of accuracy. There is a great gulf between the survey and map for the construction of a fortification on hill and escarpment and the survey and map for any other purpose that can be mentioned as detailed. In the whole range of surveying, however, one kind of survey is no more legitimate than another, all having their appropriate place, if only the scale represents the truth up to which the operator has worked.

So clearly am I of the opinion that the present recognized extensive range of surveys and maps have their legitimate provinces solely upon the condition that they shall be truthful in the pretension which they make on their face, that I am emboldened rather to suggest adding to than subtracting from the present range of map-making methods and map products.

PHOTOGRAPHIC TOPOGRAPHY FROM A BALLOON.

I deprecate any hasty, adverse conclusions on the subject which I am about to present. Experience in life shows the general tendency to resist innovation. The history of invention proves the fact conclusively. Premising then, and insisting, lest my meaning be misconstrued, upon my recognition of the facts of the possibility of failure and the existence of limitations to the applicability in places of the plan which I am about to suggest for particular purposes and places, I state now those limitations to be, so far as they are at present apparent to me, strictly circumscribed by character of country, size of scale which it is possible to use, and appropriateness of the method only to one specific kind of survey. But, as to the last clause, it may well

be urged that if only one purpose in anything be well subserved it is distinctly a gain in the affairs of men.

The idea of photographic topography from a balloon had occurred to me before I learned that it had been thought of by others and experiments tried with a view to its realization in practice. I was not surprised, however, to learn eventually that the idea had been conceived by others, knowing, as I well do, that as never before the world teems with ideas as to applied science. So far, however, as I am able to ascertain the results of these experiments, they do not stand test as results of precision, such as warrant my regarding them as representing methods capable of executing regular, accurate, reliable surveying. But, on the other hand, I venture to believe that my method, hereinafter described, if applied strictly within the conditions which I carefully note, will be found to meet all the requirements which thorough knowledge of the general subject would impose.

Given a tract of moderate accidents of surface, and, although not unwooded, destitute of forest, and I believe one would have the physical conditions fulfilled necessary to carrying out the plan of survey which I have in mind, costing very little money, and yielding immediate results, which could easily be refined upon as a final product of the survey. To take a simple case, imagine that, in a country such as I have described, a map were required to be made on and for some distance on both sides of a traverse line in process of execution. Select two stations of the line that have been occupied by the instrument for horizontal angles and mark them with two disks of white muslin, say stretched on hoops, of a size determinable by the distance at which they are to be viewed by the camera; midway on the line between the stations send up a small spherical balloon, with a camera pointing vertically downward suspended from it, and captive by four light cords, two of which should coincide in position with a vertical stripe passing around the centre of the balloon, and adjust it, in an obvious manner over the traverse line, at a height which determines the scale of the map of the area assumed to be possible of delineation. The proper elevation of the camera for the purpose of photographically including a single link of the traverse line, thus, as remarked, establishing the scale of the map, could be preliminarily established by experiment on the ground merely by setting up the camera in the usual horizontal position, so placed as to distance from a horizontal base representing the length of a maximum traverse link as photographically to reduce it to the desired scale; and as to direction so placed as to be on the perpendicular to the middle of that base.

The balloon should be centered over the point below without instrumentally aided observation, the vertically placed stripe ranging along the link, and the apparatus being anchored by light weights, with rings through which the cords could reeve, to cover the necessity of

making any adjustment of the length of one or more of them, growing out of some accident of the ground. On one of the two traverse stations representing a given link of the line the disk of white would necessarily be larger than that on the other, so as to indicate on the photograph the direction in which the survey proceeded. The camera would also necessarily play in gimbals of sufficiently easy movement, short of permitting it to oscillate with perfect freedom, of just such ease of movement as to permit it to maintain perfect horizontality. In addition to the four light cords mentioned, to be attached as guys to the balloon, for the purpose of orienting and keeping it in position, a free one, graduated downward in feet, and containing the wires in electric communication with the photographic shutter of the camera, actuated by a minute battery, would complete the whole apparatus. With due care in manipulation, the camera, lying with relation to the vertical stripe on the balloon, would be oriented with the stripe along the given link of the traverse line, and register the link essentially in the middle of the plate, and its termini within the margins of the plate.

It stands to reason that these operations would be impracticable in a high wind amounting to a gale. In a calm, however, or in moderate breezes, such as are concomitants of fine weather for field work, there is apparently little ground to doubt that the picture of the earth under the camera could be successfully taken in the manner indicated.

Any one who has flown kites, and therefore knows the stillness of them when properly constructed as to both figure and attachment, and when fully raised, can little doubt that a miniature, perfectly spherical balloon, floating in the atmosphere, held at four points equidistant from each other around the circle, would have no tendency, like an ordinary balloon, to sway, owing to the fact that its center of gravity, unlike that of the ordinary balloon, would be close to the inflated body. It would be like a kite flown from four directions, but much more stable.

How important figure and attachment are in the case of the kite is known to many persons from experience, but as many have not considered what influence those factors combined would effect in the case of a specially constructed captive balloon, it becomes here necessary to demonstrate them, through describing the construction and mode of management of the balloon adapted to the case in hand; how, through figure and attachment, the forces in play may be so combined as to produce equilibrium in the object acted upon.

In the first place, as to figure, the balloon, unlike the ordinary æronautic one, with its long neck and remote car, would be perfectly spherical, with the gimbals and dependent camera set close to its periphery. Thus closely ballasted it would, if free, have no swinging movement, and would therefore have no tendency to swing when held by centralized equiangular forces around its periphery. As for the particular feature of its attachment, which relates to the equalization

of the forces designed to retain it in position, that would be by fastening the guy cords equidistantly on a light girdle passing equatorially around the sphere as resting when ascended. It will be perceived that this place of attachment, combined with the figure and mode of ballasting mentioned, precludes oscillation, even when the lateral force of wind is introduced, unless, indeed, the balloon has not been gifted with sufficient ascensive force. The balloon, thus constructed and attached, should present stability all-sufficient for its object. But additionally to these guarantees of stability is to be added a momentary one at the critical point of time of taking the picture. At that instant the operator would stand directly below the balloon, holding in his hands the little battery and the graduated cord containing the reophores actuating the photographic shutter of the camera. At that instant he would draw the cord tense, and simultaneously complete the electric circuit of the battery, and in a small fraction of a second the picture would be taken.

The preliminary determination of the question of scale will have settled the height of the camera during the whole work, the fixing of the focus for that height, the size of the diaphragm for limiting properly the angular aperture of the objective, so as to obtain a sharp picture, and the maximum distance allowable between stations, which, however, should, for convenience sake, be as nearly equidistant as possible.

Cameras, except some of the English ones, are now made so extremely light, not over five or six pounds in weight, that the size of the balloon necessary for the purpose described would be correspondingly small. So small a superficies, moreover, as it would contain could be prepared without great pains, so that the balloon would almost indefinitely retain its gas. This gas would necessarily have to be on occasions generated by the surveyor for his own special purpose, and on such occasions would necessarily be hydrogen, heated air being inadmissible for the purpose discussed. In many cases, however, coal gas would be easy to procure, and could then be employed. The War Department balloon service now employs gas under high pressure, in steel tubes, easy of transportation. The use of such, therefore, would afford the greatest facility possible in the operation herein described.

We are now supposed to have secured, as the result of running a traverse line, in the manner described, a number of negative dry plates, impressed by instantaneous photography. These can be stored away in the dark compartments used for that purpose until such time as may be convenient to develop them. They are often thus kept perfectly safe for many months. Being finally developed they are cut off with a diamond point at such angles as will enable them to fit on the traverse line plotted on paper previously to its being sensitized.

The traverse line, as penciled to scale on paper, subsequently sensitized, would necessarily fix the directions of the photographic representations of its individual links, and the photographic representation to scale of the links on the ground would give the means for adjusting the plates on the paper; an operation, it will be perceived, thus checked by the distances to scale as actually measured between the stations of the ground; a perfect accommodation between the data, as obtained above and below, being thus effected by a slight adjustment. In order to limit to the minimum in space, the narrow wedge-shaped blanks that must occur between plates lying at an angle with each other, corresponding with their relation to nature, along the representation on paper of a traverse line thus treated, the line on the ground should be run as little zigzag as possible.

By means of lines tying on at intervals one traverse line to another, the same scheme of work could be amplified laterally. If that were done, however, one picture would overlap another, the wedge-shaped blanks would be multiplied, and the resultant print would be irregularly blurred; and, worst of all, the impressions of minute determinate objects would not be superposed. Even in this adverse case, however, the elements would be present for the draughtsman to reduce them to a coherent whole. But, on the contrary, the running of a single line, all that I advocate at present, embracing a considerable distance on each side of it, would give at once data for a very presentable map of the surface of the earth involved, and this map would readily lend itself, through the labors of the draughtsman, after having been printed in the manner described, to the refinements of being photographed or lithographed as a whole. Of course, at its inception, such a map would be entirely destitute of exact indication of vertical traits, such representation as was made of them by photography depending entirely upon the effect of perspective.

It should be obvious that, instead of running a traverse line by the method hereinbefore described, in which every position of the camera, supported by the balloon, is referred to directions and distances measured on the ground, it is possible to run a traverse line by a looser method, by means of balloon work alone. With a balloon always at a fixed height, the scale, as has been indicated, is also fixed. Therefore, if the camera be placed successively over stations Nos. 2, 3, etc., representing disks successively placed on the ground, combining in pairs, stations 1 and 3, 2 and 4, etc., then the line can be plotted on paper, and if only its terminal points be determined, a traverse line of additional accuracy would be secured, because it would as a whole be oriented. We have, therefore, within the possibilities of this method of balloon surveying, three gradations of accuracy; first, where each balloon result is referred, for each link of a traverse line, to direct angular and linear measurements on the ground; secondly, where only the two ends of the traverse line being determined, the line is wholly

The topography of the Survey with relation to its development, etc.

laid down by them; and, thirdly, where there are no instrumental determinations whatever on the ground, where the balloon camera does the whole work, by referring it to bright disks placed conveniently on the ground with reference to the topography.

I beg you to believe that I could not speak, could not indeed think, of a thing wholly untried as certain of successful accomplishment. It seems to me, however, that the plan, attempted in the manner that I have devised, subscribing to the conditions that I have sought carefully to impose, is well worthy of trial for the class of work whose requirements I have thought it might meet with the great advantage of cheapness, expedition, and picturesque delineation of certain country. I confess that I am sufficiently wedded to the belief that it would succeed, to enable me to say that I should be pleased to try the experiment with all the opportunities afforded by a centre of civilization, where are to be found, combined, artisans, material, and every facility for perfecting mechanical devices, not least among which is the counsel of experts whose assistance would render most likely, if possible, the culmination of the project in success.

Supplement C.

[Presented by Assistant Herbert. G. Ogden.]

REPORT OF THE COMMITTEE ON THE CLASSIFICATION OF THE UNITED STATES FOR TOPOGRAPHIC WORK.

The committee has further considered the question of classification submitted to it, and respectfully reports that, in its judgment, no further subdivision is necessary to complete the work outlined by the Conference. It suggests, however, that the slight changes recommended by the committee on accuracy should be adopted, viz:

In Division A, coast work—Section I—change the limits from "St. Croix River to New York" to read "St. Croix River to Delaware Bay." In Section 2, change the limits "New York to Winyah Bay" to read "Delaware Bay to Winyah Bay."

In Division B, interior work, we recommend that the word "farm" be omitted from sections 1 and 2, and in section 4, "Plateau Regions of the West" should be changed to read "Great Plains of the West."

These recommendations are respectfully submitted as the final report, and the committee requests that it may be discharged from further consideration of the subject.

CLASSIFICATION OF TOPOGRAPHY OF THE UNITED STATES.

A.—*Coast work.*

(1) St. Croix River to Delaware Bay.
(2) Delaware Bay to Winyah Bay.
(3) Winyah Bay to St. John's River.
(4) Mississippi Delta.
(5) Texas.
(6) Southern California.
(7) Northern California.
(8) Oregon and Washington.

B.—*Interior work.*

(1) Rolling lands, like New England, New York, northern New Jersey, etc., excepting the mountain ranges.

(2) Flat lands, like southern New Jersey, Delaware, the Chesapeake Bay region, and the Atlantic Coastal plain generally.

(3) Prairie lands, like those of Ohio, Indiana, and Illinois.
(4) Great Plains of the West.
(5) Plateau regions of Kentucky and Tennessee.
(6) Appalachian Mountain system.
(7) Rocky Mountain system.
(8) Sierra Nevada Mountain system.

COMMITTEE REPORT ON ESTIMATED COST OF SURVEYS PER SQUARE MILE IN TYPICAL SECTIONS ON SPECIFIED SCALE.

The following table consists of the mean value of two tables of estimates furnished the committee of the whole—one by the committee on classification, to which was given the weight of one, and one by the special committee appointed February 17 to consider this subject, whose table was given a weight of two. The latter table was made up from individual estimates of eight members of the board, those members familiar with the Atlantic and Gulf coasts estimating only for these sections, and those familiar with the Pacific coast for that section.

It is evident that, owing to lack of great experience among members of this Conference in the immense region indicated, the cost per square mile assigned to these sections must be largely approximations. Closely, therefore, as the attention of the Conference has been directed to the matter of interior surveys, only time can show how nearly it has approached the actual cost in each case.

A—COAST WORK.

	Section.	System.	Scale.	Approximate cost per square mile.	Remarks.
1	St. Croix River to Delaware Bay.	New England.	1–10000	$54	Including water areas between shore lines not exceeding one mile in width.
2	Delaware Bay to Winyah Bay.	Bay.	1–20000	27	
3	Winyah Bay to St. Johns River.	do.	1–20000	25	
4	Mississippi Delta.	Delta.	1–20000 1–40000	24	
5	Texas.	Texas.	1–10000 1–30000	15	
6	Southern California.	Pacific Coast.	1–10000	37	
7	Northern California.	do.	1–10000	43	
8	Oregon and Washington.	do.	1–10000	40	

B—INTERIOR WORK.

1	Rolling lands, like New England, New York, northern New Jersey, etc., excepting the mountain ranges.	Primary.	1–30000	25	Plane table work.
2	Flat lands, like southern New Jersey, Delaware, the Chesapeake Bay region, and the Atlantic Coastal plain generally.	Coastal Plain.	1–30000	18	Plane table, with traverse auxiliaries.
3	Prairie lands, like those of Ohio, Indiana, and Illinois.	Prairie.	1–30000	20	Plane table work.
4	Great plain regions of the west.	Great Plain.	1–40000	11	Plane table work.
5	Plateau regions of Kentucky and Tennessee.	Plateau.	1–30000	15	Plane table, with traverse auxiliaries.
6	Appalachian Mountains.	Appalachian.	1–40000	17	Plane table work.
7	Rocky Mountains.	Rocky Mountain.	1–40000	13	Plane table work.
8	Sierra Nevada Mountains.	Northern half, Appalachian; southern half, Rocky Mountain.	1–40000	16	Plane table, with traverse auxiliaries.

SUPPLEMENT D.

REPORT OF THE COMMITTEE ON THE MERITS AND DEFECTS OF TOPOGRAPHICAL INSTRUMENTS.

[Presented by Assistant Aug. F. Rodgers.]

The Committee on Instruments has the honor to report as follows:

Having examined the instruments in the office of the Coast and Geodetic Survey and conferred with the mechanician of the Survey, Mr. Fischer, and having visited the office of the Geological Bureau and conferred with its topographers and made an examination of the instruments used by them, your committee has concluded that the best forms of the plane-table and alidade in present use by the Coast and Geodetic Survey are susceptible of little improvement except in the matter of weight.

There is now in the charge of the mechanician a plane-table head, No. 83, used by Assistant Donn in the survey of the District of Columbia, which, in the opinion of your committee, is as good a form as can be devised, with exceptions hereinafter noted, simple in construction and combining several recognized desiderata, viz: a broad base plate, with two tangent screws, combining adequate strength and immobility in its connection with the plane-table board.

For general use or in a very rough, mountainous country this head, No. 83, would be too heavy, unless much reduced in size, and this would involve the loss of some of its elements of present excellence, and it is thought that by reproducing the form and size of No. 83, in aluminum bronze, and with the reduced weight of an aluminum bronze board the aggregate weight may be reduced to convenient portability for all purposes.

Your committee, therefore, recommends the manufacture of an aluminum bronze plane-table head of size and form, exceptions hereinafter noted, of No. 83, and a plane-table board of full size, to be made of the same metal and with the ends semicylindrical, with a diameter of not less than 3 inches, in order to protect the rolled portions of the plane-table sheet from the short, sharp bend over the edges of the board, as is now the case in our wooden board.

INSTRUMENTS EXAMINED IN THE OFFICE OF THE GEOLOGICAL BUREAU.

The forms of plane-table used in the Geological Survey are radically different from our best instruments, especially a head and miniature board used in the traverse work of that survey. This plane-table can only be leveled by changing positions of tripod legs and can only be moved in azimuth by hand.

Still another form is known as the Johnson patent, having ball and socket motion for level and change in azimuth, but without tangent screws. It is understood that this instrument is used in plane-table triangulation, and for interpolation of stations for topographic detail.

In connection with the miniature plane-table first mentioned, a small and light alidade without telescope is used, and it is understood that in the traverse work of the Survey the declinatoire or magnetic needle is depended upon for orientation and direction, and for determination of elevation, except in special cases, the aneroid barometer is used and referred at frequent intervals of time and distance to known datum-planes.

In traverse work, distance traversed is obtained from wheel measure, either by direct count of the number of revolutions of a wagon wheel or by the use of an odometer.

The odometer forms on sale up to this date do not meet with commendation from the office of the Geological Survey, and the experience of the chairman of your committee indorses the idea that there is great room for improvement in odometer forms, leaving an open field for invention with practical ideas of the adaptations of such an instrument. In its present form it must be treated very carefully as to rates of travel.

Your committee is of opinion that in rapid work, and especially in reconnoissance, a reliable odometer, in dust and water proof case, would be of great value in approximate determinations of distance.

Having visited the office of the Geological Bureau, your committee desires to express obligations to the gentlemen of that bureau for their kindness and courtesy in explaining methods and exhibiting the instruments used by them.

NEW INSTRUMENTS AND SUGGESTIONS OF CHANGES IN FORM.

From Buff & Berger's Hand-Book and Illustrated Catalogue of Engineer's and Surveyor's Instruments, published in Boston in 1890, your committee makes the following quotation for your information and consideration:

"The ta-chym-eter (tachymeter) or universal surveying instrument; the word is a combination of the two Greek words, "tachus," rapid, and "metron," measure. There are several words in Webster's Un-

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abridged having the first word of the combination to signify rapidity of execution. Buff & Berger describe it as "an instrument having a level on its telescope, a vertical arc or circle and stadia wires, and as adapted to rapid location of points in a survey, since it is capable of measuring the three coördinates of azimuth, altitude, and distance." Your committee has recommended the ordering of such an instrument, or in form for attachment to an alidade, for examination. From its combination of capabilities it may illustrate the usual character of a "jack of all trades," but examination must be our best guide to judge of its probable usefulness as an auxiliary to more rapid work.

OERTEL & SON, OF MUNICH.

The Secretary of the Conference has submitted to the committee a form of level known as "Meissner's Level," manufactured by Oertel & Son, of Munich, which has the advantage of rapid adjustment in horizontal plane, by means of a single vertical milled-head screw attached to the eye end of the telescope, doing away with the old form of base-plate and four foot screws.

Your committee is of opinion that the Meissner level, as described, may be made a valuable adjunct to a party equipment to obtain more rapid results where the use of a level may be necessary.

The secretary also submitted a rough drawing and description of an instrument manufactured by Bohné in Berlin, "Taschen-Niveau," the first a German word, the last French; translated they mean a "pocket level." This instrument appears to be a hand level of more elaborate form than the lock level and has an addition of a graduated arc for measurements of horizontal angles. It seems to combine the lock level and the azimuth compass or Schmalkalder, of Coast and Geodetic Survey adoption, though represented to be without a needle.

Mr. Flemer has also called your committee's attention to an instrument called a distance-measurer, which in method serves the ordinary use of our stadia or telemeter, by having a telescope mounted upon a base along which the telescope slides, and by measurement of an angle to a distant object from each end of this base the elements are obtained for determination of the distance. This instrument does away with the necessity for sending a man with a telemeter to distant points and, in effect, enables the observer to determine distances to objects without changing his station. Of course the elements of an infinitely small base and small angle of intersection of the object determined are involved, but it is suggested that for rapid work and reconnoissance the distance-measurer may be a valuable auxiliary.

Mr. Flemer, the secretary of the Conference, has furnished rough diagrams of these instruments, and they are at the service of the members for examination.

In concluding the discussion of instruments your committee recommends as follows:

For plane-table, the present forms in use by the Coast and Geodetic Survey, and for a plane-table head, No. 83, as combining all requirements, in general form, except that there is too little space between the plane-table board and plane-table head, thus making it inconvenient to manipulate the tangent screws. This would be probably remedied by lengthening the arms which connect the movement with the board. This defect is a radical one and should be remedied in reproducing the general form of No. 83. It should never be forgotten by manufacturers that the milled heads to the plane-table tangent screw and clamps are never in sight when manipulated, and for convenient and effective use should be as large as conditions and proportions will permit.

Also note exceptions to the positions of leveling screws in No. 83. They are now above, but should be below the base plate.

The plane-table head No. 83 is also too heavy, and your committee recommends experiments with aluminum bronze for reduction of weight. That the head and board with semicylindrical edge on the sheet-rolling side be made of aluminum bronze. That the alidade be made of aluminum bronze, telescope tube, standard and ruler, and that if necessary the latter be weighted to give requisite stability. The steel rulers are objectionable on account of oxidation; even when nickel-plated the rust seeks and finds weak points to come through the plating.

The verdigris on brass rulers is a constant source of trouble in soiling field sheets. It is thought the use of aluminum bronze may eliminate the defects noted.

It should not be forgotten by manufacturers of the plane-table alidade that it is essentially a hand instrument and in Coast Survey work is usually carried in the hand many hours during each day in the field. Convenient portability by hand is therefore very important. There is but one proper hand-hold in carrying it, and that should be free from all projections. A protuberance not noticeable in the first hour of a day's work becomes an unbearable nuisance at the end of the day, and the use of such an instrument continued during a season may produce a permanent injury to the hand.

It is recommended that a circular semispherical disk of sufficient diameter, with convex surface toward the hand, in carrying the alidade, be placed around the upright or pillar, and under the vertical arc and alidade screws.

It is recommended that the alidade ruler should not be solid, but should have an open center, and that each alidade should have a space countersunk in the ruler, under the eye end of the instrument, to hold a meter scale of 1 500 meters on an 1–10000 scale, 3 000 meters on a 1–20000 scale, the meter scale to be held in place by screws, removable

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at will, in case of changing scale of work; upper surfaces of scale to be flush with or in same plane with surface of alidade ruler.

From a form of alidade noted and approved by your committee, manufactured by Fauth & Co., of Washington, for the Geological Bureau, it is desired to call attention to the advantage of facing the vertical arc and vernier toward the eye end of the alidade telescope, enabling an observer to read an angle of elevation or depression without moving the alidade or changing his own position.

It is recommended that the alidade telescope diaphragm, in addition to the usual three horizontal lines for stadia measurements, should have two half lines interposed on each side of the middle line in order to double the distance of determination, the half lines not to extend more than half way from the circumference to the center of field.

A member of this Conference, Assistant R. Meade Bache, has submitted to your committee an improvement devised by him in the telemeter, and its application in coast work. Mr. Bache also presents photographs showing the manner of use, and a paper describing the various attachments.

The photographs mentioned under the textual description of the boat telemeter are submitted for inspection with this report.

As an auxiliary instrument for mountain work your committee recommends the aneroid barometer, as recently improved, desiring, however, to emphasize the importance in its use of frequent reference to known datum planes.

We recommend the trial of the odometer, and its use, if a reliable form can be found, as an auxiliary in reconnoissance and work upon the 1-40000 scale.

If the tachymeter shall be found available upon examination, it may be a valuable auxiliary in work upon the 1-40000 scale.

Your committee would recommend examination of the Meissner level, as described by Mr. Flemer.

It would be a great boon to topography if an automatic gravity level could be devised that would be superior to the present lock hand level, and yet more portable and less costly than levels of precision. It is the opinion of your committee that an automatic gravity level as suggested could be constructed, depending upon ball and socket or equivalent free motion, with a weighted pendulum below head of tripod, working on the free point mentioned and rigidly attached above to the usual form of light telescope used in spirit levels.

Subsequent to the preparation of the above report and the recommendation as to experiments with aluminum bronze as a material for plane-table apparatus, attention has been called to the inadaptability of the alloy named for alidade ruler arising from the tendency of the metal to soil the paper.

FIELD DRAWING PAPER.

The Committee on Instruments having been instructed to discuss and formulate, if possible, some practical recommendations in regard to the paper in use and furnished by the Coast and Geodetic Survey for plane-table surveys, suggests that one of the first requirements of accuracy in any plane-table survey is that the paper upon which the delineations are recorded should be as nearly perfect as possible, and certainly free from all remediable defects.

In recent years the quality and preparation of paper for field use seems susceptible of great improvement. Much of the paper found in plane-table sheets, after having been subjected to service in the field, becomes soft and fibrous, and in texture more like blotting paper than Whatman's antiquarian.

This has become a great evil in plane-table work and seems to be one universally complained of among the topographers of the Coast and Geodetic Survey.

When the aggregate cost of making any given survey contained in an ordinary plane-table sheet is remembered, and when it is remembered that the value of the survey for precision ultimately depends upon the original good quality and proper preparation of the paper, it must be apparent that it is wise economy to purchase none but the very best paper to be had and to leave no question of its best preparation uncertain on indeterminate.

Your committee, in view of the importance of this question and the length of time required for its proper investigation, would suggest to the Conference that the Superintendent be requested to appoint an office committee of field experience, to be charged with the investigation of this question of topographic field paper, and that careful experiments be made to determine the best quality and best methods of backing; the best materials, whether silk or muslin; the best adhesive materials for backing (flour paste has defects), and the best methods of seasoning plane-table sheets in the office before projections are made upon them or subjecting them to field service, so that the shrinkage of the paper after exposure in the field may be reduced to a minimum, and, further, to determine by suitable experiments and field trials the value of zilonite as a substitute for plane-table field paper. Such a committee will not be able to arrive at secure conclusions until after the expiration of one or two years, but its conclusions, if based on carefully digested facts, will be of great value to all plane-table topographers everywhere.

SUPPLEMENT E.

RULES ADOPTED BY THE CONFERENCE TO GOVERN TOPOGRAPHICAL SURVEYS IN THE SEVERAL TYPICAL REGIONS CONSIDERED.

GENERAL CONSIDERATIONS.

In the coast sections, no important modification of the methods of work and the degree of precision at present employed is practicable without material loss of accuracy, tending to lower the present standard of the charts and to impair their value to the Government and to individuals. If, in such surveys, increased rapidity or diminished cost be required, it should be attained by the omission of certain classes of detail rather than by lowering the standard of accuracy.

But in the interior, for the general purposes of topographical maps, we may reasonably relax, in some degree, the precision demanded for charts of the coast.

While gross misinformation or failure to supply information in regard to important features of the relief or routes of communication should not be tolerated in any survey of higher grade than a rough reconnaissance, it may be accepted as true that, in the present state of public needs, a map may be imperfect in the location of some natural and artificial features and yet serve ordinary purposes for which a topographic map is required, provided the general outline or skeleton of roads and streams has a good degree of relative accuracy between its different parts, and provided the critical points of the relief are correctly determined in elevation.

It is not desirable to make geographic representations for mere pictorial effects and announce the result as surveys. In all surveys for the distinctive purpose of acquiring and giving knowledge, the water courses and their sources, the drainage basins and valleys, the form and elevations of the divides, and routes of communication are the essential features, common to all sections, that should not be neglected, even when the survey is made on a small scale.

The recommendations in the following "Rules for topographic surveys," specifying the grades of accuracy which should be attained in different types of country, define the character of the surveys which, in the opinion of the Conference, best combine considerations of moderate cost, rapid execution, and usefulness for general purposes.

The members of the Conference believe that maps of a settled or prospectively valuable region made on a lower grade than that recom-

mended would not return a fair equivalent for the money expended upon them.

Should it nevertheless be necessary to make surveys of a character inferior to those that have been defined, such work should be understood and acknowledged as secondary or chorographic work.

In conformity with the resolution adopted by the Conference recommending the use of the metre as the unit of height as well as of distance, alternative expressions giving the corresponding values which in the use of the metric system should, in the opinion of the Conference, replace the customary intervals, have been added to each paragraph in which reference was made to contour intervals or precision of elevations.

The Conference is sensible that certain discrepancies are thus introduced, as when 20-foot curves are replaced in one instance by 5-metre and in another case by 10-metre curves, or when 40-metre intervals are recommended as substitutes for 100-foot intervals. It thinks, however, that the advantages to be gained outweigh nice considerations of consistency.

The fixing of intervals with the foot as the unit was largely controlled by precedent and by the desirability of preserving intervals which should be aliquot parts of 100 feet.

In making the radical change to the metric system it has seemed desirable to base our intervals, in a general way, upon a somewhat similar consideration of the 100-metre intervals as grand units of elevation, and at the same time to introduce in some cases rather smaller intervals than the 20-foot, and in other cases to give somewhat greater freedom and rapidity by increasing the interval, the change of unit enabling us to bring about these variations in a perfectly natural way. The use of the 40-metre interval in certain cases is the only exception to the rule of making the intervals aliquot parts of 100 metres. (This interval is recommended in regions where it is thought that 50-metre curves would not adequately represent the relief and where the use of 25-metric curves is not justified by the character of the country.) Even in this case the interval is an aliquot part of 200 metres, so that little inconvenience, if any, would be occasioned by its use.

It should be observed also that the adoption of the metre as the unit would in general widen the interval between the curves, reducing the number of them, but without any material loss in representation of the forms, and to some extent would lessen the cost of the surveys.

In order to render perfectly clear its views with reference to consideration of different sections of the United States, the Conference would state that the coast and the interior are at present to be regarded from entirely distinct standpoints.

Under the fundamental law and the subsequent practice of the work, the surveys of the coast have comprised fitness for purposes of navigation and for military operations. As the necessary consequence

Rules adopted by the Conference for topographical surveys in typical regions.

of the law and of the long experience of the Survey on the extended coasts of the United States, the scales appropriate to different types of coast topography have so assimilated themselves to the respective needs of each section (type, purpose, and scale according with one another) that to the mind of the expert they represent one complete and harmonious whole. In consequence of these facts the Conference has found little difficulty in the discussion of the topographical treatment applicable to the coast sections. In a word, the treatment by the Conference of the coast of the United States in establishing topographical rules for its survey, is virtually but a re-affirmation of all that in the history of the Survey has preceded this action.

The case presented by the interior is, however, entirely different. For this part of the country preëminent purpose for prospective surveys is not at present defined by law. In the absence of controlling purpose, the consideration of the question reverts to the necessity of fixing upon scale and limits of detail for different sections solely upon the basis of giving for different topographical types the maximum of information for general purposes, combined with the minimum expenditure of time and money.

While the Conference is not called upon to formulate definite purpose for such hypothetical surveys, some of the purposes which they subserve may, in a general way, be easily stated. Geological purposes they manifestly include, military purposes in a general way, if they should be so required, hypsometrical data, extent and relation of watersheds, preliminary locations of railroads and other roads, distances between towns, etc.

That such surveys would include all of these and other purposes is apparent, but only the future can decide what preëminent purpose or purposes, beyond uses generally specified, such surveys will fulfill, and therefore the Conference concludes its consideration of the surveys of the interior without attempting to define their preëminent purpose in a manner analogous to that applicable to the coast.

Division A—Coast Work.

NEW ENGLAND SYSTEM.

Section 1.—*St. Croix River to Delaware Bay.*

(1) The scale of 1–10000 should be used throughout this section.

(2) All points determined by intersection and prominent trees or other objects useful as land or pilot marks should be as accurate as the scale and material worked upon will permit.

(3) On the sea coast and on the shores of navigable rivers, projecting points of shore line, outlying rocks, and ledges should be determined with the accuracy of occupied stations or "points determined by intersection."

(4) The delineation of the low water line should be as precise as the physical conditions of the coast will permit. On moderately steep shores, where slight variations of low-water level would not produce great horizontal displacement, the low-water line may be shown with nearly the same accuracy as high water. But where the slope of the bottom is very gradual, so that slight variations of the low-water level would produce great horizontal displacement, the low-water line should be sketched freely, simply to indicate the presence of flats, or that there are channels through the flats that will require development by the hydrographer.

(5) Outlines of unnavigable rivers and ponds should be within 25 metres of their true positions, their forms being preserved as far as practicable.

(6) Narrow streams, flowing through thickly wooded valleys or wooded swamps, should, if practicable, be shown within 50 metres of their true positions.

(7) The line between hard land and marsh, when well defined, should have the same limit of error as contiguous shore line. When not well defined its delineation must be left entirely to the discretion of the topographer.

(8) Outlines of woods should not, in general, be in error by more than 50 metres.

(9) All railroads and main wagon roads should be delineated with such accuracy as the scale and material will permit.

(10) Graded roads through public or private grounds of considerable extent should have nearly the same accuracy as main wagon roads, the degree of precision to be dependent upon the relative importance of such roads.

(11) The deviation from accuracy of wood roads and other byroads at any place between their terminal points should not exceed 50 metres.

(12) Houses and barns should be shown within 10 metres of their true positions.

(13) In cities, towns, or large villages the built up sections should be indicated by shading, without showing individual buildings or accompanying details.

(14) The general shapes and dimensions of buildings should be preserved without undue attention to detail.

(15) Small or unimportant outbuildings should be omitted.

(16) In surveys on the scale of 1–10000 no fences should be omitted except those inclosing small areas around houses and barns or other unimportant subdivisions.

(17) The elevations of prominent objects, to be used as points of reference in subsequent work, should not be in error by more than 3 feet or 1 metre.

(18) The elevation of ordinary plane-table stations should be correct within 5 feet or 2 metres.

Rules adopted by the Conference for topographical surveys in typical regions.

(19) The heights of the surfaces of lakes and large ponds above mean sea level should be determined with the same accuracy as that adopted for points of reference.

(20) Within this typical area the contour interval should be 20 feet, or 5 metres.

(21) Contours may be deflected in sketching above or below their true planes, to represent particular accidents of ground, by an amount not exceeding 5 feet or 2 metres, vertically. Beyond this limit auxiliary curves should be used, if necessary.

(22) In open country, on slopes of less than 5°, sketched contours should be correct within half an interval. On steeper slopes they should be within one interval. In heavily wooded, hilly country this limit may be exceeded; but in low country, even if heavily wooded, the summits or height of land should not be in error more than 5 feet or 2 metres.

(23) Contours should cease at the edges of steep banks, and the bluffs should be indicated by hachures.

(24) In cases of importance (for purposes of navigation or future comparison), the crest lines of the bluffs should be delineated with nearly the same accuracy as the main shore line but in ordinary cases an approximate location will suffice.

BAY SYSTEM.

SECTION 2.—*Delaware Bay to Winyah Bay.*

(1) The scale of 1–20000 should be adopted for this section, except near large towns, where 1–10000 should be used.

(2) Accuracy of detail. In work on 1–10000, all details should be as accurate as in section 1.

The following paragraphs refer exelusively to work on 1–20000.

(3) Prominent objects used as signals or pilot marks should be determined with the greatest accuracy which the scale and the sheet will permit.

(4) The outer shore line should be correct within 25 metres.

(5) Inside navigable channels should be located within 25 metres; and the widths of such passages should not vary more than 10 metres from their true values when the whole width does not exceed 200 metres.

(6) Unnavigable rivers, creeks, and ponds should be shown within 50 metres of their true positions.

(7) Narrow streams through wooded valleys or swamps should, if practicable, be shown within 100 metres.

(8) In out-of-the-way marshes, broken up by numerous unnavigable creeks and openings not thoroughfares, such passages may be very freely generalized; but their junctions with main bodies of water should

be within the limit of error adopted for shore-line work of similar character.

(9) Marsh lines should follow the same rule as in section 1.

(10) Outlines of woods should in general be correct within 100 metres.

(11) Low-water line should be expressed as well as practicable under the local conditions, and generally as specified in section 1.

(12) Railroads and main wagon roads should not be in error more than 20 metres, the centers of the roads to be taken as their true lines.

(13) Park roads should have the same degree of accuracy.

(14) Ordinary byroads, wood roads, and trails may deviate 100 metres between terminal points.

(15) Houses should be shown, subject to the limitations specified for section 1, except that the limit of error (as in the case of roads) may be 20 metres; also barns, when of sufficient size or prominence to make them desirable. Special care should be taken to show isolated buildings, in the woods or elsewhere, but their positions need not be as accurately determined as in section 1.

(16) Only those fences which are notable features should be shown upon the map.

(17) Elevations, when given, should be as accurate as in section 1.

SECTION 3.—*Winyah Bay to St. John River.*

(1) Scale as in section 2 (1–20000).

(2) Accuracy of detail and relief as in section 2.

"DELTA SYSTEM."

SECTION 4.—*Mississippi Delta.*

(1) Scale 1–20000 for main river channels and 1–40000 for all other work.

(2) Accuracy of determination should be in proportion to the scale used, based upon that adopted for section 2.

"TEXAS SYSTEM."

SECTION 5.—*Texas.*

(1) Scale 1–10000 at important passes and 1–30000 on all the rest of the coast.

(2) Accuracy should be in proportion to scale, as above.

"PACIFIC COAST SYSTEM."

SECTION 6.—*Southern California.*

(1) The scale should be 1–10000.

(2) For features of the shore line and other detail the accuracy of determination should be as in section 1.

Rules adopted by the Conference for topographical surveys in typical regions.

RELIEF.

(3) Up to 500 feet of elevation 20-foot contours should be expressed, or up to 200 metres of elevation either 5 or 10 metre intervals should be expressed, according to the character of the region.

(4) Above 500 feet 50 or 100 foot contours will suffice, or above 200 metres either 20 or 40 metre intervals will suffice.

(5) The determination of elevations, when the relief is expressed by 20-foot or 5 or 10 metre contours, should be as accurate as in section 1. When only 100-foot or 20 or 40 metre contours are used, the elevations of points of reference should be obtained within 6 feet or 2 metres and of ordinary plane-table stations within 10 feet or 3 metres of their true values.

(6) When using 20-foot or 5 or 10 metre contours, the limit of error in sketching should be the same as in section 1.

(7) When only 100-foot or 20 or 40 metre contours are necessary, their deviations from accuracy should not exceed one interval (100 feet or 20 or 40 metres) when it is practicable to attain this degree of precision.

SECTION 7.—*Northern California.*

(1) Scale of 1–10000 should be used.

(2) Accuracy of detail as in section 1.

(3) Contour intervals and accuracy of contouring as in section 6.

SECTION 8.—*Oregon and Washington.*

(1) Scale of 1–10000 should be used.

(2) Accuracy of detail as in section 1.

(3) Contour intervals and accuracy of contouring as in sections 6 and 7.

DIVISION B.—INTERIOR WORK.

"PRIMARY SYSTEM."

SECTION 1.—*Rolling lands, like New England, New York, Northern New Jersey, etc., excepting the mountain ranges.*

(1) The scale should be 1–30000.

(2) Plane-table points used as signals should be as accurate as the scale and material worked upon will permit.

(3) The shore line of navigable rivers and lakes should not be in error by more than 30 metres.

(4) In work upon this scale, the topographer should show all railroads, public roads, and all other roads (except such as could not be used as thoroughfares), canals, farm-houses (when accessible), swamp areas, and wood outlines.

(5) The general characteristics of streams and ponds should be shown, without too close attention to their minute sinuosities.

(6) Conventional signs should be used for the representation of houses, villages, and towns.

(7) Barns, outbuildings, and fences should be omitted, except when the barns are very prominent or are landmarks.

(8) Elevations of main points of reference should be within 5 feet, or 2 metres, and of ordinary plane-table stations within 10 feet, or 3 metres.

(9) The contour interval should be 20 feet or 10 metres.

(10) Summit contours should be correct within 10 feet or 3 metres, and when practicable valley-floors should be correct within the same limit.

The location of intermediate contours should be as close as the scale and condition of the region will permit.

COASTAL PLAIN SYSTEM.

SECTION 2.—*Flat lands, like southern New Jersey, Delaware, the Chesapeake Bay region, and the Atlantic coastal plain generally.*

(1) The scale should be 1–30000.

(2) The amount and accuracy of detail should be the same as in section 1 of the interior.

(3) In this kind of country the representation of relief would be impracticable without great expense for leveling.

PRAIRIE SYSTEM.

SECTION 3.—*Prairie lands, like those of Ohio, Indiana, and Illinois.*

(1) The scale should be 1–30000.

(2) The amount and accuracy of detail should be the same as in section 1 of the interior.

(3) In general, the relief should be represented when practicable.

(4) The contour interval should be in general 50 feet, or 20 metres, but in special cases the topographer may use curves of smaller interval at his discretion.

GREAT PLAIN SYSTEM.

SECTION 4.—*Great plains of the West.*

(1) The scale should be 1–40000 and signals and other points of reference should be determined as accurately as the scale and the sheet will permit.

(2) All streams and dry water courses should be shown. The threads of the streams, being quite indefinite in position, may be freely generalized between the inclosing bluffs.

Rules adopted by the Conference for topographical surveys in typical regions.

(3) The bluffs should be represented by hachures and may be freely generalized, the general forms being preserved as far as practicable.

(4) Railroads and main routes of communication should be shown and should be accurate within 40 metres.

(5) All isolated houses, as indicating population and culture, should be shown within the same limit of error.

(6) Villages and towns should be conventionally represented.

(7) Fences inclosing large areas should be shown, but all other fences should be omitted.

(8) Forests, if any, should be shown, also belts of woods along water courses.

(9) Contours should be shown at vertical intervals of 50 feet, or 20 metres, and in case of sudden accidents of ground the topographer should use such contour intervals as he may think necessary.

PLATEAU SYSTEM.

SECTION 5.—*Plateau regions of Kentucky and Tennessee.*

(1) The scale should be 1–30000.

(2) Signals and other details should be represented with substantially the same accuracy and fullness as in section 1 of the interior.

(3) The elevations of points of reference should be correct within 10 feet, or 3 metres, and of ordinary plane-table stations as near that limit as possible.

(4) This section being densely wooded and very broken, the contours can only be approximate; the crests and valleys should receive the most attention, to represent their elevations and grades, without too much refinement in horizontal positions. Contours should be shown at vertical intervals of 50 feet, or 20 metres.

(5) When the plane-table can not be used advantageously, other suitable instruments may be utilized as auxiliaries. In country of this sort a survey to be made within a reasonable time and at a practicable cost must be chorographic rather than topographic; that is, the minute features of the relief must be overlooked and only the general forms represented.

APPALACHIAN SYSTEM.

SECTION 6.—*Appalachian Mountain system.*

(1) The scale should be 1–40000 and signals should be determined as accurately as the scale and material worked upon will permit.

(2) In general, this section will come under the same treatment as that outlined in paragraph 5, section 5.

(3) Railroads, canals, and all other routes of communication should be shown, the railroads and canals within 20 metres and other routes within 40 metres.

(4) Streams and ponds should be shown, when practicable, within the limits of the scale.

(5) Single houses should be shown within 40 metres.

(6) Villages and towns should be represented by conventional signs.

(7) The elevations of points of reference should be determined within 10 feet, or 3 metres, when practicable, and other stations should be determined as closely as possible.

(8) The contour interval should be 100 feet, or 40 metres, with 50-foot or 20-metre auxiliary curves, when necessary.

(9) The hill forms should be generalized, taking care that the summits and valleys be as accurate as circumstances may permit.

(10) Rocky cliffs, precipices, etc., should be indicated by hachures or shading, in addition to the contours.

ROCKY MOUNTAIN SYSTEM.

SECTION 7.—*Rocky Mountains.*

(1) The scale should be 1–40000 and the degree of accuracy should be the same as in section 6, except that in the mountains proper more generalization may be permitted.

(2) Existing detail should be shown as closely as the scale will permit.

(3) This typical section being much more open than section 6, much greater accuracy may be attained in the determination of relief. The plane-table can generally be used.

(4) The elevation of points of reference should be determined within 10 feet, or 3 metres, and the elevation of other stations should be as near this limit as practicable.

(5) The contour interval should be 100 feet, or 40 metres, with 50-foot, or 20 metres, auxiliary curves, when necessary.

(6) The summits and valleys should be represented with all practicable accuracy, but intervening forms may be freely generalized.

SECTION 8.—*Sierra Nevada Mountains.*

The northern part of this section is generally wooded and should be treated like section 6, except that the contour interval should be 50 or 100 feet, or 20 or 40 metres.

The southern part resembles section 7 and should be treated in the same way.

SUPPLEMENT F.

REPORT OF THE COMMITTEE ON INSTRUMENTAL METHODS, APPROXIMATE COST OF SURVEYS, ETC.

[Presented by Assistant J. W. DONN.]

The consideration of the resolution referred to the committee necessarily involves the subject of methods now in vogue representing the execution of topography of the highest standard compatible with the scale and purpose of the work as a basis for comparison.

It may be advanced as an axiom that the purpose in a general way indicates the scale; otherwise, given the purpose of the survey, and the magnitute of the scale is approximately suggested. In the order of classification of the general grades of surveys, those known as "critical" occupy the highest place both in the measure of accuracy and cost. Performed mainly for constructive purposes, they are of such a character as to fully subserve those purposes both for present use and future needs. In considering the cost per square mile of such surveys it is obvious that the smaller the vertical distance between horizontal contours, the greater the relative expense of the undertaking. It is safe to assume that the survey of a given area upon which contours of 1 foot (v. d.) are delineated, will cost approximately three times as much as the same area with 5-foot contours. The cultural and natural details otherwise form but a comparatively small part of the cost of such work.

In general terms it may be stated that in a survey upon any one of the scales used in critical work—1-600, 1-1200, 1-4800, or 1-5000—with elevations developed by 5-foot contours, the cost should not exceed $900 per square mile. In exceptionally difficult areas, with high and complex configuration, this would be exceeded, while upon ground simple and with low configuration the cost might not exceed $100 per square mile. All cases of large scale work, however, should be treated according to the character of locality, and it is therefore manifestly impossible to make a hard and fast rule as to cost when conditions of surface are so varied. An experienced topographer need not be greatly perplexed to determine the question of cost after having obtained a comprehensive view of a prescribed locality; but to say in advance of such action what should be the expense of such a survey, would be as difficult and unreliable as a weather forecast six months ahead of time. But special cases of very large scale critical work may be relegated to a place outside of the subject under consideration.

The usual scales of work—1–10000, 1–20000, 1–30000, 1–40000—are applicable to the general purpose of delineating the topography of a country. In the execution of accurate surveys, each has a locative value and a delineative power commensurate with its place in a definite system of measurements. While it is apparent that a scale of 1–10000 may be used in a locality where a comparatively full and accurate survey could readily be obtained through the medium of the smaller scales, without loss of time or increase of cost, it is equally apparent that the smaller scales could not be made to measure up to the possibilities of the former. In a country of varied configuration and largely diversified detail, so full as to justify all the care and refinement possible with the larger scale, there may occur a very considerable tract of marsh land, sandy waste, or wood land, virtually barren of topographical details. Uniformity requires the extension of the large scale work over the whole area, although the smaller scale would completely fill all the needs of these almost featureless parts. But the combination of these areas, embracing the largely detailed and the featureless within the same project, serves the purpose of decreasing the cost of the whole. This shows that the scale does not, within any reasonable degree of certainty, indicate the cost. All things being equal, the purpose in a general way defines the scale, and the scale the cost of the survey. But here the question of personality comes in as an important element of uncertainty; for of two individuals, A and B, A finds no difficulty in accomplishing a given result in a specified time, while B, from inherent difference of temperament, mental or physical disqualification, may not, with the expenditure of his best powers, be able to reach the standard of A. This differentiation of personal attributes or conditions enters, unfortunately, into the question of expense. In quality of work, B may be quite equal to A, but in quantity far inferior. It follows, if this be so, that as topographers must differ very much in respective excellence the variation among them in judgment in this matter must take a much wider range than that in the case cited. It becomes thus apparent that differences in judgment, as applied to determinations, even within any given scale, are an element of unassignable difference in value.

For the purpose of eliminating as much as possible error growing out of difference in judgment among men as applied to topography, reliance must be placed upon a hand-book for topographers, such as is in contemplation as the concluding portion of the labors of this Conference.

Taking the various conditions cited above and the differences between men in skill, physical qualities, and judgment, the difficulty of determining the exact cost of any given work is very great, that is, if the area to be surveyed is large and varied and the time limited, requiring the united efforts of several topographers to accomplish it.

The instruments used have but small part in altering the relative

conditions among a number of men. By a combination of the best methods of instrumental work and the selection of topographers according to their several abilities, the cost of work may be materially lessened without loss of accuracy, but the degree of economy still remains an unsolved problem, for it must not be forgotten what a large part climatic conditions may play in the matter. To illustrate the effect of this, reference is made to the survey of Mount Desert Island. In the first year of that work, a season of four months' duration, one-fourth of the time was lost by fog and rain. In the second year a still longer time was involved, and in the third in one month alone there were twenty-two days of fog, when nothing could be done in the way of field progress. It is hardly necessary to say that the cost of that work was largely increased by the vicissitudes of weather.

For the work of the future, the consideration of which is placed upon us in compliance with the instructions of the Superintendent for a statement of "Methods by which work may be rendered more rapid and less expensive without material loss of accuracy," the following statement is presented, beginning with a classification of the several scales of topographical work, their sphere of usefulness as to locality and adaptation to the purpose of the work to be performed, and an approximate average cost, in which estimate due consideration is given to the several retarding influences heretofore mentioned.

Four orders of scales are given, each embracing two classes or variations of country.

Order I	Class A—Regions of large population, high configuration or relief, largely varied cultural and natural detail. Scale, 1–10000. $60 per square mile.
	Class B—Regions of similar character as to population and detail, but low relief. $50 per square mile.
Order II	Class A—Regions moderately populated, high relief, but of inconsiderable cultural and natural details. Scale, 1–20000. $40 per square mile.
	Class B—Regions similar as to population and details, but low relief. $30 per square mile.
Order III	Class A—Regions of rolling prairie lands, moderate as regards population and details. Scale, 1–30000. $15 per square mile.
	Class B—Regions described as plateau timberless, sparse population, few natural details. $10 per square mile.
Order IV	Class A—Regions of grassy lands, or lands not susceptible of much cultivation, small areas of timber. Scale, 1–40000. $8 per square mile.
	Class B—Arid lands or sandy plains, mountainous regions, and flat forest lands. $4 per square mile.

The above estimates embrace only the cost of maintaining parties in the field while executing the triangulation and topography. The total cost, including the salary of the chief of party would increase the amounts from 25 to 50 per cent.

In each of these classes there are vast areas where climatic conditions vary greatly from great heat to long continued intense cold, excessive rains, and almost entire absence of rain.

By curtailment of details of minor and comparatively unimportant characteristics, the classes under Order I may readily be placed under the terms as to cost of the classes under Order II. There need be no decrease of accuracy, but less completeness as to details. The important desideratum, of course, in all classes is accuracy in as large degree as the scale of the work will permit. In the fourth order great generalization of details will be necessary, especially in delineating the relief.

A rule that may be applied to the subject is that the lower the class the smaller the degree of refinement possible and the more infrequent the recourse to instruments of precision.

The limit of error should never exceed the capacity of the scale. In other words, each feature indicated should be truthfully represented; *i. e.*, while the minor details of a ridge or valley may be freely generalized, its general form and the direction of its axis should be correctly given. In like manner the outlines of a lake or pond should represent its general relative proportions and location.

ON INSTRUMENTS.

The capabilities of that instrument of instruments, the plane table, and its unequaled usefulness in every order of work named above are fully understood by all the topographers of the Coast and Geodetic Survey. As an instrument for rapid and accurate determination of position, it stands superior to all others. Its auxiliary, the telemeter, in facilitating the location of details not readily determinable by intersection, and the combination of the two with the Y level and rod, is all that can be desired in large scale work. In the scales of work designated by Orders III and IV other auxiliaries may with advantage be used. The small railroad transit with vertical arc is an invaluable instrument in running traverse lines in regions of timbered lands where points of observation for plane-table stations are infrequent. The sextant also has its use in minor traverses for the location of road junctions, the general course of streams and their confluence with others, and other objects more or less hidden from view of the plane-table. The French water-level is most excellent for road profile and contour sketching and the Locke level in a less degree can be used to considerable advantage. The small traverse plane-table may be used in small scale work and secure good results. Other very valuable auxiliaries recommended are the distance measure of Oertel & Sons (Munich) and the tachygraphometer, both of which will largely aid in the production of rapid and economical work.

An important reduction in the cost of topographical work may be effected by placing the secondary and tertiary triangulation in the hands of the topographer. A large number of points quite useless to the topographer are determined by parties unfamiliar with topograph-

ical methods. The cost of such triangulation being charged against the topography of the locality, economy can surely be gained by uniting the two under one chief of party. No appreciable delay would be caused in advancing the topography and no points would be located and determined that did not bear a closely defined relation to its needs.

The recently improved aneroid barometer can sometimes be used advantageously, but it is extremely doubtful if it will be found judicious or economical in topographical work, excepting in cases of extreme difficulty. In a long discussion of the subject of barometric measurements of heights, Mr. G. K. Gilbert, of the Geological Survey, notes the effect had upon the barometer in high winds. In a series of observations made upon Mount Washington he detected some anomalous fluctuations which he "was enabled to trace to the influence of the winds upon the tension of the air in the observatory, and this influence was found to be so great during the prevalence of gales as to vitiate the record of the barometer. The error amounted in some instances to the one hundred and eightieth part of the atmospheric pressure and affected the determination of altitudes by more than 100 feet."

The influence of humidity and temperature and the errors of observation all make up a series of unsatisfactory conditions, not easy to eliminate by the best process known to practical men.

Mr. Gilbert, in his conclusion, states that—

In any survey which is based upon triangulation, the points occupied are intervisible, so that if their distances are not great it is possible to ascertain their relative altitudes by means of vertical angles and with a degree of accuracy not attained by the barometer.

The topographer is able to compute the relative height of all points visible to him from any station, provided their distances become known, by measuring the angle of elevation or depression which they subtend; and, since other stations of his system are always included among the points of observation, he is able in this manner to carry through his field a connected system of altitude determinations.

When, in the progress of geographic refinement, the stations of the topographer approach so near to each other that the precision of the measurement of altitudes by angulation becomes equal to the precision obtained by means of the barometer, barometric hypsometry receives at once a formidable competitor. Indeed, it encounters an invincible antagonist; for the expense of reading vertical angles, when it is performed as a mere accessory to the ground work of the topographer, is notably less than the expense of transporting and observing barometers. The most thorough geographic work will therefore dispense altogether with the barometer.

When, in connection with this statement, the practical method of the determination of altitudes by the plane-table alidade is considered, it will be seen how expensive and slow are the methods of barometric measurements. From any two stations forming a base of proper length a large number of altitudes can be readily determined. With the plane-table, therefore, a topographer thoroughly familiar with its

capabilities, is never at a loss as to the means by which any difficulty encountered is to be overcome.

The camera, in connection with the plane table, may be occasionally usefully employed in the representation of the profiles of mountains and hills in bold relief. It can not be said that its sphere of usefulness is in any case so great as to make it a formidable rival to the plane table. While its delineation of clearly discernible topographical features may be more readily obtained as a picture or series of pictures as seen by the eye, the exact projection of those lines of sight making up the picture upon a geographic plan would be a slow process, and one inferior in precision to the lines of intersection showing the same plan as drawn upon the plane table. And when the obscure or non-discernible features of a locality are borne in mind, and there are but few localities where such are not found, the limitation of the camera must be fully seen.

Applying the remarks of Mr. Gilbert, previously quoted, in regard to the comparison of barometric and angulated altitudes, and changing expressions to suit the relative influences of the two instruments, we may say: When in the progress of geographic refinement the determining lines of the alidade drawn upon the plane table approach so near the lines of sight, as seen in the pictures represented upon the photographic plate, that the precision of their intersections becomes equal to the precision obtained by means of the camera, photographic topography encounters an "invincible antagonist;" for the expense of drawing those lines in the field, where it is a mere accessory of the general work of the topographer, is notably less than the expense of producing the pictures of the locality, the development of its lines from camera stations, and their projection to scale in a geographic plan; to which may be added the surely attending circumstance that a large amount of detail is beyond the reach of a camera, excepting by a multiplicity of views from a large number of stations, the projection of which to plan would be conducive to delay and confusion.

We may rest satisfied that in the plane table we have the highest type of an instrument for topographic work yet devised. In it we find simplicity combined with precision, rapidity of execution with economy of labor, and adaptability of means to the end to be attained.

In the accomplishment of topographical work of minimum expense, combining accuracy with rapidity of execution, it is unnecessary to look beyond this instrument for the means to reach the desired result. The proposition may be stated thus:

Given the character of a locality, its relative relief, its cultural and artificial features in terms as stated in the arrangement of classes, and the cost may be approximately expressed. If it is desired to conduct an inexpensive survey over a country classed under a high order, the method of accomplishing the desired result will be apparent. Accu-

racy in all prominent features must be first attained, and then the degree of refinement in the less important details must give way to the exigencies of the case. Often it may be necessary to ignore many details to keep within the limits of available means.

An estimate for the approximate cost of topographic work in the typical regions is herewith submitted; the figures include triangulation and exclude salaries of officers.*

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*Refer to Supplement C for approximate estimates adopted by the Conference.

SUPPLEMENT G.

FACTS AND POSSIBILITIES IN TOPOGRAPHIC WORK.

[By Assistant Aug. F. Rodgers.]

The evolution of modern navigation from the old time sailing packets, plying between European ports and those of the United States, often blown helplessly out of their true course by adverse winds for weeks at a time, up to the present "ocean greyhounds" rushing through the sea on schedule time with almost the speed and precision in arrival and departure of railroad trains, is due in no small degree to the excellence of modern charts and the precise knowledge placed in the hands of the navigator through the Coast Survey of the United States and kindred surveys abroad.

Carefully determined positions of light-houses, of headlands, of outlying rocks, and of coast line; careful observations to determine the magnetic declination of the compass needle, that mainstay of the mariner, his guide over the pathless ocean, careful observance and record of tidal phenomena all along our coast, and exact methods of triangulation on which to base our topographic and hydrographic surveys, were all necessary, before safe and reliable charts could be placed in the hands of the mariner to enable him to properly guard the human lives and valuable cargoes dependent upon his intelligent care.

A "pretty good chart only" for the purposes of rapid steam navigation, where a ship approaches or runs along the coast at a speed of a mile in three minutes, would be as little acceptable or useful to the modern mariner as "a pretty good egg only" to the average man—an offense in both cases.

Our topographic maps along the seaboard, made for chart purposes and for military use, have been made to show in detail contours of level, summit elevations, the positions and relative size of rocks lying off or along the coast; in a word, have furnished truthful topographic delineations of the lands adjacent to the seaboard, including all cadastral or cultural features, combining results of value to the mariner, to military defense, to the farmer, and the land owner.

Made as they have been made, our surveys have furnished a basis of truth, a solid foundation at least, to build county and State maps upon, along the whole seaboard of the United States; and in surveys of the interior, wherever our geodetic work has been carried it is accepted, and it may well be, as unquestioned authority upon which to base State work.

Facts and possibilities in topographic work.

If the topography of the Coast and Geodetic Survey should be carried further inland, the work already done will afford a starting base for future operations, but the special conditions of exactitude and detail which govern the seaboard work do not there exist.

As an illustration of the difference of conditions, there are still great areas in the great West, west of the Rocky Mountains, so sparsely settled that at this day the treatment of cadastral or cultural features need have no place in the discussion of questions of proper scale or time or method in making surveys of them.

Many of these areas are rainless as compared with eastern areas, and some of them nearly waterless, and thus not open to ready settlement, but the valleys and plains of most of these areas would "blossom as the rose" if moderate irrigation could be provided.

The hardy growth of sage brush of various kinds, covering millions of acres of wild lands in the public domain of the United States, seems from repeated experience in many different localities to indicate a latent strength and fertility in the soil that water and the plow may develop into rich arable land.

The people of the United States need never be hopeless of these lands of theirs after the recorded experiences of the French Government and engineers in bringing areas of the Saharan desert under cultivation, through abundant water furnished by artesian wells.

The areas spoken of are cut frequently by intercepting ridges of high and rock-ribbed mountains, with elevations running up to 10 000 or 12 000 feet above sea level, their summits covered with snow for several months in each year.

These areas are a part of the great farm belonging to the United States, and if our population increases for the next one hundred years as it has in the past, they must all be brought under occupation; and as the crowding of areas, now well filled by population, becomes more and more felt, money must be spent and experiments made to prove the value of these lands for homestead purposes.

In this view alone it seems evident that a certain amount of defined knowledge in regard to relative elevations, present natural roads, mountain passes from valley to valley, water courses where they exist, and, in a word, all information which may lead to a determination of the present and prospective values of these wild lands, would be of great use to the Government.

It seems further evident that the survey required for the purpose indicated might be on quite a small scale and much more generalized as to details than would have been either practicable or profitable upon the seaboard of the country.

It is believed that even such generalized surveys would be very greatly enhanced in value and without material increase of cost by basing them always upon carefully determined triangulation points,

thus affording the means of joining intelligently and accurately at some future time successive areas at first unconnected.

These stations of triangulation once occupied and marked would be available for future work for all time, where settlement should introduce new features and develop necessity for a more complete topographic survey.

The triangulation would not need to be elaborate, but rather of a quality to carry with it constant evidence of the degree of accuracy attained, and thus avoid with certainty the element of indefiniteness.

This would be accomplished by the occupation of all the stations in any main scheme—thus checking the filling of triangles—and by double determination of all inferior and subsidiary stations.

These determinations by theodolite would serve as a basis for locating topographic work, even if detached, in such a way that when desired it could be connected intelligently with other detached areas.

A theodolite of 10 inches diameter reading to 3 seconds would be quite equal to the requirements of the triangulations intended to be outlined.

A plane-table for topographic detail, with an odometer and several aneroid barometers as auxiliaries, would in some cases facilitate progress.

Absolute elevations at distances from the seaboard could be determined trigonometrically and from known datum planes. The barometer, if carefully used in settled weather, would furnish approximate elevations.

In 1875, with mercurial barometers, starting from the datum plane of the Central Pacific road at Redding, Cal., by synchronous observations, a Coast Survey party obtained the elevation of Strawberry Valley at the foot of Mt. Shasta, and by similar observations at the summit of the mountain and at Strawberry Valley on two days at stated hours, 9, 12 and 3 p. m., the elevation of the summit was approximately determined to be 14,440 feet* above sea level, with a plus or minus correction of 50 feet.

With the admission that results proportionally close for general contours in a preliminary survey would be satisfactory, it is evident the barometer could be used to advantage.

Of course in unsettled weather the barometer is not to be depended upon for elevations, and the "pumping of a barometer" as sailors call it in a storm, has been noted many times, and especially in narrow gorges in California, when with every blast of wind succeeded by a momentary lull, the index of the instrument would respond, indicating by its rapid motion increased and suddenly diminished pressure of the atmosphere; but this does not militate against the use of the barometer as an auxiliary for elevations, under proper conditions.

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*An approximate determination by railroad levels and vertical angles gives 14,350 feet.

Facts and possibilities in topographic work.

It has been shown that the work done upon our seaboard by the Coast and Geodetic Survey has been generally first-class, and that it could not otherwise have met the requirements of modern navigation; leaving out of consideration the advantages in such complete surveys to studies of military defense, and the incidental advantage to the farmer, the landowner, and the great land traveling public of our country. It has been shown also that surveys with equivalent information of interior regions, largely the property of the nation—a part of the national domain about which little is authentically known and where authentic information must be desirable to the owner, just as the possibilities and the capabilities of outlying and unimproved lands of the private farmer would be a valuable demonstration to him—could be obtained at little expense compared with the cost of surveys of seaboard areas.

There are areas yet unsurveyed which would require much less detailed representation than the areas adjacent to the seaboard, but more than the unsettled areas of the great West; and a wise discrimination will be necessary in making recommendations between these classes as to the proper scale for fieldwork, the amount of detail that should be required, and that just expenditure for which a truthful equivalent in results may with certainty be rendered to the nation.

Unfortunately, the appearance of a map is not always evidence of authentic value as to methods or results in the survey upon which it is based; and unless its groundwork and foundation be true, and may form a useful basis for development, the money and time expended in its decoration is only like expensive ornamentation on a rickety house built upon a frail foundation.

SCALES OF TOPOGRAPHICAL SURVEYS OF FOREIGN GOVERNMENTS AND THE UNITED STATES.

Great Britain	1–500 for cities and
	1–2500 for country in general.
France (formerly)	1–2000 and 1–5000 for fortified places and vicinity.
	1–4000 for country in general.
France (now)	1–10000 for country in general and
	1–20000 for mountainous districts.
Algeria	1–40000 in the northern parts and
	1–100000 in the southern parts.
Belgium	1–20000.
Denmark	1–20000.
Holland (old survey)	1–25000.
Holland (new survey)	1–5000 (1874).
Sweden and Norway	1–20000 for settled districts and
	1–50000 and 1–100000 for the northern regions and high mountains.
Germany	1–25000 in general and
	1–10000 special localities.
	1–500, 1–1000, 1–2500 for engineering purposes.
	1–125, 1–250, 1–500 for cities and vicinity.

Austria	1–12500 for special localities and 1–25000 in general.
Switzerland	1–25000 in general and 1–50000 for mountainous districts.
Italy	1–25000 in general. 1–50000 for mountainous districts. 1–10000 for certain seaports and vicinity.
Spain	1–25000.
Portugal	1–50000 and 1–100000.
Russia	1–21000 for settled districts. 1–42000 for northern provinces and for (also 1–84000) the great steppes of the east.
Asiatic Russia	1–17000 to 1–84000.
Roumania	1–50000 and 1–100000.

UNITED STATES GOVERNMENT SURVEYS.

Lake Survey by the Engineer Corps U. S. Army	1–10000
Coast and Geodetic Survey	1–10000 1–20000 1–40000
Coast and Geodetic Survey, special surveys	1–600 1–1200 1–4800, etc.
Geological Survey	1–31250 1–45000 1–62500 1–125000

SUPPLEMENT I.

REPORT OF THE COMMITTEE ON "METHODS OF UNITED STATES AND FOREIGN GOVERNMENT SURVEYS."

[Presented by Assistant W. H. Dennis.]

Resolved, That a committee of five (5) be appointed by the chairman, to report on the methods of making topographical surveys by the several Departments of the United States and Foreign Governments, and to recommend such changes or improved methods, if any, as they may deem of advantage to the work as now executed by the U. S. Coast and Geodetic Survey.

Your committee, to whom the above resolution was referred, beg to state that the subject has been quite exhaustively investigated, considering the limited time at its command, and to submit the following papers as its report, viz: Critical surveys for special purposes in the United States by Assistant J. W. Donn; topographical surveys in the United States and in Italy by Assistant D. B. Wainwright; surveys in England and France, and notes on surveys in Belgium, Denmark, Holland, Portugal, Roumania, Russia, Spain, Sweden and Norway, by Assistant W. C. Hodgkins, and on Germany, Austria, and Switzerland by Assistant J. A. Flemer. Mr. Flemer also submits a paper on photogrammetry. On this subject a subcommittee was appointed, who

thus far have been unable to make the field experiments necessary for a full report. It is, however, the opinion of the committee that photogrammetry would be of little or no value in making surveys of exact scale.

UNITED STATES COAST AND GEODETIC SURVEY.

In a paper on cartography submitted by Mr. A. Lindenkohl of the Coast and Geodetic Survey we beg to refer with entire approval to the statements on page 603 relating to linear measure and to the plane of reference, and from the investigations your committee concludes that it is unable to recommend any method of making topographical surveys that would be an improvement on that now in use in our own service. Should we however be called upon to make surveys over more extended areas, in mountainous countries, and on smaller scales, we believe that the use of the tachymeter attachment to the alidade; the distance measurer by Oertel & Son, Munich, and the improved aneroid barometer would be of great advantage.

CRITICAL SURVEYS FOR SPECIAL PURPOSES.

[Presented by Assistant J. W. Donn.]

Surveys of this character have been undertaken from time to time by the Coast Survey during the past thirty-five or forty years. In many instances the work has been done for strictly comparative purposes, in the interest of a scientific study of the laws governing the formation of shoals, the dynamic action of wave motion and tidal currents in degrading or building up the shores. The survey of Sandy Hook, Rockaway inlet and beaches, Coney Island and Vineyard Sound, Hatteras inlet and cape, Cape Fear river entrance and the Mississippi delta are among the localities where special resurveys have been required because of ceaseless fluctuation in their character and conditions.

The special surveys of New Haven, the shores of the Delaware at Philadelphia, the Taunton river, Baltimore harbor, and others, are instances in point of work done largely in the interest of improvements of harbors and harbor approaches.

The survey of Portland city and harbor which was urgently called for during the superintendency of Prof. Benjamin Peirce, was made under a special appropriation authorized by the municipal authorities of that city. It had for its object the improvement of the water front along Fore river (the Harbor proper) and the Back Bay, and to secure data to enable a commission to make a scientific study of the question involved, viz: a large reduction of the water area of the Back Bay or basin which at low water presented a vast expanse of unprofitable flats through which a narrow winding stream made its way. The city au-

thorities deemed the subject of such importance as to devote $15,000 to a most accurate survey of the whole area covered by the city, Fore river, and the bay above mentioned.

The work was begun by the Coast Survey in the summer of 1868, and the methods adopted were quite similar to those usually practiced by civil engineers, with the exception that a plane table was used for the determination of the relief indicated by contours of 6-foot interval, instead of a transit. These contours were run in by level determination of cross-section stakes, distances measured by steel tape and plotted upon plane table sheets.

In 1869 the survey was continued, the summer months constituting the season of practical work. The manner of prosecuting the survey was essentially changed from the method used the previous year. The plane table, in its complete adaptability to the highest as well as the lowest orders of surveys, was used to the fullest extent of its locative power. The scale of 1–1200 = 100 feet to the inch, represented in its full plan every cultural detail in the city and suburbs and every feature of the relief capable of being expressed in terms of the 6-foot contour. Instead of cross-section stakes, as in the previous summer, each contour was traced by the level rod directed by the level, and its distance from the station of the plane table determined by steel tape measurements. Railroad curves were located by plane table intersections, as were the corners of houses, angles of streets, curb and building lines.

In the survey of Craney Island, Virginia, made in 1874 by request of the Ordnance Bureau, U. S. Navy, an advance was made in the method of measurement by the free use of the telemeter. The scale of this survey was also 1–1200, but the contour interval was 1 foot. How efficiently the telemeter was found to be applicable to the development of the relief by that small interval is shown in the sheet of that survey.

The most extensive survey on so large a scale as 1–4800 ever performed in the United States was carried over the area of the District of Columbia, about 60 square miles, between the years 1880 and 1891. The methods of work used for the Craney Island survey were adopted. Based on a sufficiently minute triangulation, the plane table and telemeter and the wye level and rod were used for all determinations of details. The relief was elaborately indicated by contour intervals of 5 feet. The datum plane furnished by the Engineer department of the District of Columbia was that on which was based all the levels made for grades of streets and sewers in the city of Washington. The survey being especially made for the purpose of extending streets and avenues beyond the city limits, and involving the whole subject of future grades when those extensions should become necessary, it was entirely appropriate that the levels of the survey should conform to the datum given.

From this datum along all roads, avenues, and railroads, lines of levels were run, and after careful checking in the usual manner benchmarks were placed in positions convenient to all parts of the field.

On methods of United States and Foreign Government Surveys.

Where roads were infrequent, lines were run across country so that the sum total of all the bench-marks established for purpose of contouring ran high up into the thousands. The plane-table stations were established so as to easily reach every part of the field and so close together that it was generally possible to encompass the distance from station to station when intervisible, by readings within the range of the telemeter. The mode of procedure was as follows: The plane table having been placed in position by a graphic solution of one of the several methods of the three-point problem, the level in the meantime having had its elevation above a near bench-mark determined and the target of the level rod fixed so as to give the bottom of the rod when its target was in the line of sight with the level, the measure of a contour interval above or below the bench-mark, the party was in readiness for making an advance movement. The rodman then began his journey along the imaginary horizontal line presenting his rod vertically held for the observation of the leveler at each noticeable change in the configuration of the ground, and when the target had found its place in the line of sight in the level, the telemeter rodman presented his telemeter held as nearly as practicable perpendicular to the line of sight from the alidade, for the reading of the distance between the plane-table station and the level rod when held at the point in the contour. This being read and plotted on the plane-table sheet, the rodman advanced along the line as far as the distance could be conveniently read from the plane-table station. Generally two and sometimes three contours were thus run from one level station as far in both directions as the scale of the telemeter would safely permit. After the limits of the distances as read from the plane table were reached, a turning point below the elevation of the level for higher or lower contours was fixed and the level moved to another position and its elevation determined.

In this manner many thousands of miles of contours were run over the area of the survey.

The plane-table operator in this work had no idle moments, his attention being constantly fixed on the movements of his leveler and rodmen, excepting when the new position of the level was being taken. Thus his eyes and hands were busy in drawing lines of intersection, determining the numerous other details, and drawing the permanent lines of his work.

METHODS OF TOPOGRAPHY IN THE UNITED STATES.

[Presented by Assistant D. B. Wainwright.]

"Quot homines, tot sententiæ"—many men, many minds—may well be taken as the text of any account of the topographical surveys of the United States.

One of the most troublesome questions which arise in treating the subject is to give a good definition for the words "topographical survey." Anyone who may go out and make a sketch of a certain area, jotting down the relative positions of certain features of the earth's surface, may return with the idea that he has made a topographical survey. Another with more purposes in view, more requirements to be satisfied, will name the foregoing a sketch, and to fulfill his wants will use a compass and some simple means for measuring distance. With these he will determine a number of prominent features, sketch the intervals between them, plot the whole to scale on a sheet, and, unless he is a man of rare modesty, the words "topographical survey" are sure to appear conspicuously in the title.

And still another, from his point of view, will call the preceding result a reconnaissance, and will proceed to map the country with more refined methods, employing a greater number of instruments, and obtaining a greater number of details.

And so we advance in an ascending scale, until the large cadastral surveys are reached, where even the ground plans of small houses are faithfully shown, and the relief is expressed by contours of small interval. The varieties of instruments used have been as numerous as the different classes of work performed.

The simplest instrument that I am aware of was employed far back in the thirties. In this case, I am credibly informed, the topographer traversed some hundreds of miles of New Jersey roads, using the stride of his horse for measuring the distance, and, having on the back of his left hand a quadrant marked off in ink, he determined the angular turns by sighting his right hand over this most novel graduation.

This instrument, I believe, was only employed by its inventor, but is mentioned here, not only because it is unique on account of its originality and simplicity, but it plainly exemplifies the fact that a Coast Survey officer can use "cheap" instruments when necessity requires him to give cheap results.

From this simple type there is a range of choice through many forms of varying complexity, until we arrive at the modern plane table as manufactured for the Coast and Geodetic Survey, which, while it is still susceptible of further improvement, stands in my estimation preeminent as the instrument for the topographer.

The military expeditions sent out by the Government in the early part of the century into the then unknown West, all obtained in their explorations material for charting the country traversed. With long

distances to pass over and great hardships to contend against, the instrumental work was necessarily of the crudest sort.

The geological reports of the various States all have maps accompanying them. These, however, were mostly compiled from land surveys, and the geologists almost invariably complain of their inaccuracy, and urge the necessity of regular topographical surveys.

The surveys of Hayden, Powell, King, and Wheeler were all intended to cover in a short space of time large areas of country of which little was known, and a large portion of which consisted of mountains of the most rugged description. The details were determined from meander lines, generally controlled by triangulation, and the elevations attained by barometer.

The survey of the Adirondack wilderness in New York, by Colvin, was made in a more precise manner. With a base derived from the triangulation of the Coast and Geodetic Survey a scheme was developed covering this region with a number of well-determined points. The observations were made with a theodolite, and careful attention paid to details. The prominent peaks, summits, ridges, valleys, and lakes were determined by intersections from the triangulation stations, and those of minor importance sketched in.

For ascertaining the heights, and plotting the relief, a mercurial barometer was employed—the aneroid proving too unreliable. Dudley Observatory was used as a point of reference for the whole survey, and numerous base stations were determined by synchronous observations. These stations were situated at the foot of the mountains, and served to check the observations taken at a greater altitude, when local atmospheric disturbances rendered a direct comparison misleading.

An error of 70 feet, Mr. Colvin states, might have crept into the determination of some of the peaks but for this precaution. It was also noted that the mountain-locked valleys were peculiarly subject to irregular changes, local in character.

The inventive faculty seems to be well developed in the true topographer; and it is hardly a source of wonder when we recall the endless variety of difficulties he is constantly meeting, requiring prompt solution, and which are only overcome by a resort to clever devices. One instance of this talent has already been given. Mr. Colvin illustrates his report with several examples.

The height of some inaccessible peak being desired, it was determined from one of greater altitude by occupying a point on the side of the latter where a telescopic level would indicate that a horizontal line would pass tangent to the top of the former. The distance being known from intersections, the combined correction for curvature and refraction is added to the altitude of the point of observation as given by the corrected barometric reading, and the result will be the desired height of the distant peak.

In the case of a lake so hidden away in the forest that it was impossible to fix its position by ordinary means, a calm night was chosen, and observers being stationed at known and commanding points a rocket was fired from the edge of the lake at a given signal and observed upon with the instruments. Should this lake also have such an extent of shore line as to make it requisite to determine more points along its borders, Mr. Colvin would obtain these by having recourse to a modification of the old expedient of boat and mast, so familiar in Bowditch for a harbor survey.

Selecting a tree growing on the edge of a semicircular bay, a signal is set up at its foot. Another is placed 52·4 feet higher up on the trunk. Taking a sextant and setting the vernier to read 3°, a search is made along the shore of the bay until the upper, as reflected, coincides with the lower signal; this point will then be 1000 feet distant from the tree. From this base the triangulation proceeds.

The Engineer Corps of the U. S. Army seems to have borrowed the traditions of their English brethren of the Ordnance Corps. On the Survey of the Northern and Northwestern Lakes, conducted by the Corps of Engineers, the topography was executed in substantially the same manner as the English Ordnance Survey, with this exception: the distances on the meander lines were measured by means of stadia. Based on a rigid triangulation, the topography was obtained by setting up a theodolite at one of the stations and running a traverse line to another triangulation point, measuring the angles and distances on the way to such details as were visible from the line. The probable error for any one of these lines was found to be 1 in 649.

The contours were drawn from heights determined by vertical angles. The interval was from 10 to 20 feet. The scale 10000.

Here it seems pertinent to inquire into some of the causes which led the Ordnance Corps to reject the plane table, since their great survey has exerted a powerful influence on the choice of methods elsewhere. With the whole of Europe unanimous in favor of the plane table, why should Great Britain discard it? The answer is readily found when we call to mind the climate of those islands, which is proverbial for its inclemency. With a survey executed on a large scale, with numberless distances to be plotted, it is a serious objection in such a country to have to depend, as is necessary with the plane table, on a material like drawing paper, which expands and contracts according to the moisture in the atmosphere, not equally in all directions, for that would be merely a change of scale, but about one-fifth more in length than in breadth.

In our climate, if due care is taken as to the exposure of the sheet, and on work well controlled by triangulation, this contortion is of less importance. However there are always some days in a season when the conditions would be favorable for plane-table work were it not for the dampness in the atmosphere. This time we utilize in erecting sig-

nals, sketching, etc., but in Great Britain the number of such days is so out of proportion to the number of good days, that the use of a plane table with a sheet made of backed paper is out of the question. Happily we seem now in a fair way to obtain a substitute for paper, and thus get rid of a serious objection to the use of the plane table in all climates.

As to the comparative cost of the two methods, the testimony is in favor of the plane table. It is a specious argument to estimate the cost of topography per square mile in one country by one method and compare it with the cost per square mile in another country by another method. The conditions may be very different. A favoring climate, a simple terrene, and a lack of check work may all make the more expensive process appear the cheapest. But we have in this country two pieces of work where the conditions were substantially the same—the Lake survey before referred to, and our survey of some portions of New England. Both were executed with the strictest attention to accuracy; both had long stretches of shore line; the climatic conditions similar, if not more favorable to the Lake Survey. Gen. Comstock reports the cost of the topography of the Great Lakes as $151 per square mile; a former superintendent of the Coast and Geodetic Survey (C. P. Patterson) places the highest cost per square mile for the New England coast at $97.

Another point urged in favor of the traverse method is the number of checks it receives before being accepted. Capt. Boyce in the discussion of Mr. Josiah Pierce's lecture on the use of the plane table enumerates a long list practiced in the Ordnance Survey. Now all these checks take time, and add to the cost of this final result. Given a proportionate amount of time and money the work of the plane table can always be checked. From two commanding stations the accuracy of the survey of a large area can be determined with unequaled rapidity. It is a lack of check of some of the work done in this country which has thrown discredit on this method. An attempt to cover large areas at small cost, has resulted in the acceptance of all matter, good, bad, and indifferent, and from this mass of incongruity is evolved a map, fair in appearance and false in detail.

METHODS OF TOPOGRAPHICAL WORK ADOPTED BY THE U. S. GEOLOGICAL SURVEY.

The Geological Survey, whose methods and instruments are more akin to our own than those of any other bureau under the Government, commenced during the past decade numerous topographical surveys in various parts of our territory. Mr. Henry Gannett in Science, July 1887, outlines the methods pursued.

The scale for the published maps adopted for populous regions was 62500, or about one inch to the mile; for the Southern and Central

States, 125000; for the sparsely settled regions of the Rocky Mountain Plateau, 250,000; and the field sheets to be twice the scale of the published maps. They represent all natural features of drainage and relief in degree of detail proportional to scale. The relief is expressed by contours, and the interval, according to the horizontal scale and degree of relief of the country, ranges from 10 to 200 feet; the smallest contour interval accompanying the largest scale and *vice versa.*

The topographic work is in part prosecuted by plane table, using it by the method of intersections and in part by traverse methods. Both were used in Massachusetts. New Jersey was traversed with a compass and odometer, the relief being determined by the wye level; the District of Columbia by telemeter traverse; the Appalachian region mainly by compass and odometer, the elevations by barometer and vertical circle. In Missouri and Kansas, data were compiled from the General Land Office and the heights measured by barometer, making use of railroad profiles wherever practicable. The Dismal Swamp, Virginia, was traversed by plane table and odometer; the contour interval was 5 feet, determined by the wye level.

	Scale.	Cost per square mile.	
Massachusetts.	62500	$12·00	No △^{n}
New Jersey.	62500	6·50	Some △^{n}
District of Columbia.	62500	7·30	
Appalachian region.	125000	3·00	
Missouri and Kansas.	125000	·90	

From Mr. Gannett's "Survey and Map of Massachusetts," National Geographic Magazine, Vol. I, No. 1, I have abstracted the following:

For convenience the field work was done on a scale of 30000; the relief was expressed in contour lines traced at vertical intervals of 20 feet. The map represents all streams of magnitude sufficient to find place on the scale; and all bodies of water, as lakes, swamps, marshes, etc. It also contains all towns, cities, villages, post-offices—in short, all settlements of any magnitude—all railroads, and all roads with the exception of such as are merely private ways; all public canals, tunnels, bridges, ferries, and dams. There were excluded private roads, fences, various kinds of crops, and at first isolated houses; but subsequently, in response to the urgent wish of the Commissioners, the Survey consented to locate the houses upon the field maps. Forest areas are shown on the original sheets.

There were upward of 500 triangulation points, mostly determined by the Coast and Geodetic Survey, but in part by the Borden Survey and the Geological Survey.

Throughout most of the western part of the State the work was done entirely with the plane table, using the methods of intersections. The plane tabler, starting with three or more locations upon his

sheet, furnished by the triangulation, expanded over the sheet a graphic triangulation. This was done beforehand, before the sheet had an opportunity to become distorted by alternations of moisture and drying. This done, the plane tabler went on with his usual routine work, locating minor points and sketching the topography in contours.

Elevations were determined as the work progressed with the vertical circle of the alidade, and minor differences of elevation between points whose height was known were measured by the aneroid barometer.

The large plane table of the Coast and Geodetic Survey was first used, then the smaller form; finally the one designed by Mr. W. D. Johnson, of the Geological Survey, which is substantially a modification of the ball and socket movement, was adopted.

In the undulating, forest-covered regions of the southeastern part of the State, the roads and principal streams were traversed with theodolite and stadia; and from these lines the country lying between them was located and sketched.

The area surveyed by the method of intersections exclusively comprises 3 500 square miles, about three-fifths of the State. In this area 3 123 stations were occupied by the plane table, or slightly less than one to the square mile. Besides these, 17 846 points were located in this area by intersections, making a total of 20 969 locations within the area, or 6·2 horizontal locations per square mile. In the same area the heights of 34 893 points were measured, being 10 per square inch of the published map.

The area surveyed by the traverse method is 2 800 square miles. In this area 5 615 miles of traverse lines were run, being 2·2 linear inches per square inch. In running these lines 46 524 stations were made with the theodolite, being 8·3 per linear mile of traverse and 18·6 per square inch of map. The number of measurements of height was 92 561, being 37 to the square inch. The plane-table party consisted of one man and assistant, and was furnished with a horse and buggy. In the traverse work the party consisted of a traverse man and a rodman. No horse and buggy was furnished. The average output per working day of the plane tabler has been for the whole survey 3·1 square miles, and of the traverse man 2·8 square miles.

DETAILED TOPOGRAPHICAL SURVEY OF THE CITY OF ST. LOUIS, MO.

A large scale (1–2400) survey of St. Louis, Mo., has been in progress since 1889.

It is based on points derived from the transcontinental triangulation of the Coast and Geodetic Survey. Numerous bench marks were established and the average error of closure of level lines was 0·013 feet per mile. The party consists of 1 topographer, 1 recorder, 3 stadia men, and 1 utility man. A Buff & Burger transit is employed, reading horizontal angles to 10 seconds and vertical angles to 1 minute.

The stadias were 12 feet long and distances could be read by them to 458 metres.

Intermediate distances between bench marks were determined by vertical angles.

All traverse lines began and ended at a triangulation point, or other station on connecting lines. The contour planes were 3 feet apart. Number of elevations per acre, 3·65. Scale, 2400. Contour planes, 3 feet apart.

Cost of triangulation....	$1812·00
Cost of leveling........	2762·00
Cost of topography.....	6060·00
Cost of office.....	6266·00

Average cost per square mile $724·50, or $1·13 per acre.

Central Park, Fairmount Park, and other localities were surveyed with the plane table by corporations and private individuals, but the processes employed do not present any peculiar features that I am aware of.

The purpose of this paper has been to note briefly the various methods employed in this country and to give a succinct description of several surveys, each one of which seemed typical of a class.

Our own topographical surveys illustrate the healthy growth of an organization in which the vital principles of accuracy, adaptability, and improvement are manifest.

The end to be attained has always been kept in view, and the purpose has always specified the means for its attainment. A rigid adherence to a high standard of accuracy where small errors would involve the peril of many lives or great wealth has been sturdily maintained against a constant and persistent pressure for more, if inferior, results.

Yet when the purpose has been the greatest amount of information in the shortest time, and preciseness a minor consideration, our methods have proved sufficiently elastic to adapt themselves to the needs of an army in a strange country.

During the war of the rebellion large areas were covered by Coast Survey officers attached to the various armies, and yet such was their skill that their sketches often misled many into supposing them to be finished instrumental surveys.

A story is told of a certain engineer officer who was deceived in this manner, and after locating his earthwork by means of a sketch growled vigorously because he could not also compute the amount of excavation by it. In all probability the sketch covered 4 square miles and was the result of half a day's work.

These military surveys are an example of our most rapid, and the cadastral surveys for harbor and city improvements specimens of our most painstaking and accurate work.

In nearly all the plane table was employed and has proved its efficiency.

Methods of topography in the United States.

In closing I would state that there are certain conclusions which force themselves on one in going over, even hastily, the subject of topographical surveys, and they are:

(1) The plane table in this country is the most suitable instrument for all classes of work.

(2) It is still susceptible of improvement.

(3) A new material for plane table sheets is urgently needed.

(4) Compilations from any source are to be distrusted and only accepted after careful verification.

(5) A thorough system of inspection and checks should prevail in all plane-table work. The method should not depend alone, as it sometimes does, on the unknown quantities of the topographer's skill and honesty. A good inspection would soon pick out the incompetent, compel the careless man to do more accurate work, and the skillful and conscientious topographer would be stimulated by having the difficulties and excellences of his labors appreciated.

TOPOGRAPHICAL METHODS OF THE U. S. COAST AND GEODETIC SURVEY.

[Presented by Assistant D. B. Wainwright.]

An exposition of the instrumental and personal processes necessary for a precise and intelligible representation of nature; especially those processes peculiar to the plane table, and which constitute its special power and opportunity, sets forth the chief method of topographical work used by the Coast and Geodetic Survey.

This paper is largely composed of extracts from Assistant E. Hergesheimer's treatise* on the plane table, re-arranged for this purpose and with additions which seemed necessary to bring out more clearly some points of field practice.

For a full description of the instruments and their adjustments, explanations of the three and two point problems, various tables and plates, the reader is referred to that treatise.

As our surveys are intended to serve not only as charts of our coast and harbors, but also for the many purposes of navigation, commerce, and military defense, the topographical details to be mapped are numerous and must be quite accurately determined. Two scales, the 10000 and 20000, have been found the most appropriate for the various classes of field work; 10000 from Maine to Delaware Bay on the Atlantic coast; also for the whole Pacific coast; and 20000 for the remainder of the Atlantic and Gulf coasts.

The details might be shown on smaller scales, but it has been proved from experience there would be nothing gained, either in economy or

*U. S. Coast and Geodetic report for 1880—Appendix No. 13.

rapidity, from their use, owing to the tax on the topographer on account of the more minute drawing involved.

As in all plane-table surveys it is important that sufficient points shall be determined from a measured base, at such distances from each other that, when plotted on the scale of the survey, they may be reached by the rule of the alidade over the intervening spaces, it will be presumed that this has been done, as is usually the case in the Coast and Geodetic Survey, and that the sheet to be used on the table has these points accurately plotted, so that they bear the same relation to one another as the corresponding points of nature.

Signals having been erected at each triangulation point and also on all other prominent hills within the area of the sheet, where they would be useful in providing additional control, the next proceeding will be to occupy one of the former points.

Care should be exercised in choosing the day for this portion of the work, as it is essential that the plotted points of the triangulation should be tested, and new ones determined from them in the most favorable weather.

The chief and controlling condition in working with the plane table, and without which no accurate work can be done, is that the table shall be *in position;* that is, that all lines joining points on the sheet shall coincide in direction with the corresponding lines of nature.

When the table is in position at any determined point, any object in view may be observed through the telescope, and the edge of the rule being kept sharply on the point occupied, a line drawn along its edge will be the direction of the object observed; but as this determines only one element, that of direction, it will be necessary to determine its distance from the point occupied either by measure or by intersection of this direction by a direction from some other fixed point, which will intersect the first direction at an angle when practicable, not less than 30° nor more than 150°; all intersections can be verified by a direction from a third point.

When a direction has been drawn from a station to any undetermined point that can be occupied, the position of the point may be determined by occupying it with the table, and putting the table in position by the line drawn to it, and *resecting* upon a signal whose corresponding point is plotted upon the sheet.

Before leaving the station, lines to all prominent objects, natural or artificial, within the scope of the station should be drawn. If the height of the station be important, this should be determined, both as a guide for the lines of equal elevation in the immediate vicinity, and as a point of reference for determination of heights from other stations.

This should conclude the work at this point, and the topographer now proceeds to occupy others until he is satisfied that enough positions have been accurately fixed over the whole sheet.

No definite number of positions, either in regard to number of square

inches of plane-table sheet, or square miles of the region to be surveyed, has been determined upon. The nature of the country has had more influence in fixing the most desirable number of controlling points to a given area than any other consideration. Where the country is open and the triangulation stations commanding it are well placed, a few additional stations may suffice.

Enough, however, should be furnished so that there will always be several within the reach of the ruler, and not too near the edge of the board, no matter what portion of the sheet is exposed upon it.

The number of plane-table or secondary points may be considered sufficient when they are grouped together near enough so that a new station may be determined from them at any place on the sheet where one may be necessary for obtaining details or checking traverse lines.

From the foregoing it will be seen that the triangulation stations control the main plane-table stations determined as secondary points of control, and these in turn control the ordinary plane-table stations from which the topographical details are obtained. All details of sufficient importance to justify their exact location should be determined by intersections or measured to from the instrument.

There is often occasion for a nice discrimination in using the plane table (involving time, labor, and the command of ground) between an excessive number of telemeter measurements, with comparatively little sketching, and the reverse.

The former, besides entailing a loss of time, tends to dull the skill of the topographer as an expert sketcher, in giving less opportunity for estimating distance, relative proportion, and the characteristic expression of topographical features.

The latter will result in producing a map deficient in accuracy at critical points.

The best method is to adapt the two processes to the scale and the character of the detail. When the scale is large or the cultural features numerous, the frequent use of telemeter measurements becomes a necessity to insure sufficient accuracy. On the other hand, when the scale is small and the region sparsely settled a liberal number of stations should be occupied so as to obtain views of a feature from more than one point, and the details sketched in by the eye aided with a small number of telemeter readings.

For filling in this skeleton with all the details that may be desired, the plane table is set up at any desired place where a good view of the surrounding features can be obtained. If this place has not been previously determined, it is now effected by means of the resection of lines from three known points (the three-point problem). Next, angular readings by means of the arc of the alidade are taken on objects whose altitude is known, and the height of the instrument above the datum plane thus found.

Since no topographical map can be complete without some systematic representation of the undulations and changes of slope of the surface of the ground—terrene—caused by the oscillations of the earth's crust, erosion, abrasion, or artificial works, various modes have been devised for such representation.

The two methods of surveying curves of equal elevation are known as the *regular* and the *irregular* methods.

The *regular methods* include—

(1) Surveying and leveling the skeleton and its traverses.

(2) Surveying and leveling the profile lines.

(3) Surveying and leveling the base of each level section.

(4) Surveying and leveling the parts of several level sections from one station.

(5) The division of the terrene into squares, triangles, or parallelograms.

The *irregular method* consists in determining the positions and heights of a number of characteristic points of the terrene, and in determining from these the traces of the curves.

This is the method generally used in surveys embracing such areas as the sheets of the Coast and Geodetic Survey on scales of 1–10000 and 1–20000.

The vertical intervals at which curves should be drawn must be determined by the object and necessities of each case, and, in a measure, by the gentleness or abruptness of the slope. As a rule, with such features as prevail on the New England coast of the United States, intervals of 20 feet are found to develop the form with sufficient detail on 1–10000 scale, but, for purposes of construction, intervals of 5 feet or even less are often found desirable on larger scales.

In abruptly mountainous and comparatively inaccessible regions, where sketching must be relied upon, 100-foot curves may suffice to develop all necessary features.

Having already drawn the ground plan of the locality, the alidade is used both as a level for the observation of objects the same height as the instrument, and for measuring angles of elevation and depression to such of the platted details, whose position at critical points of the contours would materially assist the topographer in tracing them.

No rule can be laid down as to the number of elevations that should in this manner be determined from each plane-table station or for a given area. It will depend on the skill of the topographer and the modeling of the terrene. The number will be adequate when he is confident of tracing by their aid the contours with an accuracy sufficient for the scale and the purposes of the survey.

It would indicate careless and slovenly work if the contours were found, on examination, to deviate frequently from their true position on the sheet more than half an interval for a slope of less than 5° in an open country. Where the slope is steeper or in wooded regions a

greater latitude is permissible; but even here in representing the crests of ridges, prominent hilltops, and valley floors this limit of half an interval should not be departed from for good work.

Each case will present some peculiarities which must be met, as they are presented, by the topographer's own resources; and as on the ordinary scales of topographical surveys a limit of minuteness of detail must be fixed, a sound management of work, established by experience, will find its strength resting upon a discrimination between important and trifling features, and a ready decision of what to omit as well as what to include. Labor may be spent in the development of small individual features which are comparatively lost on the scale of the work, while the features characteristic of the forms produced by oscillation, erosion, or abrasion, indicative of the forces producing the same and which give distinctive character to the terrene, may be lost sight of in the too careful attention to minute details.

Having completed the work at a given station, the topographer proceeds with his party and instruments to an adjoining locality, where he selects a new station from which he can gather the details of an area bordering upon the one last surveyed. In this manner, by successively occupying points over the whole expanse of the sheet, the skeleton map is filled in.

In a wooded country, where it is impossible to find open space with range sufficient to see enough points for determination of position by resection, it is necessary to run traverses along the roads with offsets to such lateral features as it may be practicable to reach without the expenditure of excessive labor and time in opening lines of sight. The levels, when necessary, are carried along the traverse lines by angulation with the vertical arc of the alidade, taking back and fore sights at the alternate stations.

For this purpose the standard table is used on main roads and wherever the details are important and numerous. For, with compass, the deflections of the traverse will be only approximate, and with a transit instrument the necessity arises for platting with protractor on a sketch, with less accuracy and facility than the table affords.

When, however, the traverse line is unimportant, and few features present themselves to be noted; an auxiliary plane table oriented by a declinatoire or a transit fitted with stadia wires may be employed. When this method is pursued with a second table the forward station, as given by the telemeter, is not occupied, but another is chosen in advance of it, and from which it can be seen, where the instrument is set up and oriented by the declinatoire. Sighting the alidade to what is now the back station, the distance is read and platted along the edge of the ruler, and the point so determined represents the one occupied by the table.

It is apparent that this method is more rapid than the regular one employed on main roads, but far less precise.

The regular method consists in starting the traverse line by occupying some point previously determined and sending the telemeter ahead to a place selected for its advantageous position, in reference either to the surrounding features or facility in obtaining a new section of the traverse. Having sighted to this point, read and platted the distance, short guide lines should be drawn along the edge of the ruler at both ends and numbered or lettered, so they may be identified from others of like character. The table is then moved to the forward station, approximately oriented, and the platted point carefully plumbed over the one on the ground.

The alidade is now placed on the table and put in position by bringing the edge of the ruler close up to the guide lines; then by revolving the table until the vertical wire bisects the rod or signal, left for that purpose at the last station, it is oriented.

In running traverses, great care should be taken to sight as low as possible upon the fore and back signals, so as to avoid any error of deflection that might arise from inclination of the signal poles.

The stadia methods in plane-table surveys for measuring distance are either two horizontal fixed lines on glass, or webs in the diaphragm of the alidade telescope, which subtend variable lengths on a divided staff in proportion to distance; the staff having been experimentally divided on measured distances; or a micrometer eyepiece to the telescope, with two horizontal webs in the diaphragm, one of which is movable by a finely-cut screw, subtending a given length distinctly marked by two targets on a rod. The angle, as indicated by the rack and the divisions of the screw head, giving the distance from a table experimentally made on measured distances.

By these methods 400 metres may be measured within a probable error of 1 metre, which, on the usual scales of plane-table work, is inappreciable, and within the probable changes of the dimensions of the paper from its hygroscopic properties.

By the method of fixed lines in the diaphragm the angle remains constant and the chord variable, and by the micrometer method the chord remains constant and the angle variable.

For topographical reconnoissance a micrometer eyepiece in the telescope for distance measure is probably better than fixed lines in the diaphragm, because in the use of the former the chord on the staff or other object remains constant and can be made longer or shorter for greater or less distances, the variable angle being read with the micrometer. On a conspicuous tree or on the face of a prominent rock, especially when on the shore of a body of water, a vertical distance the length of the chord of the experimentally made micrometer-distance scale may be marked with whitewash, so that it may be used for the observation of distance from any point from which it may be visible.

Topographical methods of the Coast and Geodetic Survey.

A lone tree on a divide may for this purpose be valuable for a large arc of visibility.

Where it is necessary to make a topographical survey in advance of the determination of points by triangulation, a reconnoissance is first made for the location of a base line and selection of points to be determined with the plane table.

The base is then measured with sufficient accuracy for the purposes of the survey.

Signals having been erected at selected points, the extremes of the base are occupied with the table, and the points, as far as may be reached with good intersections, determined from them, and lines of direction drawn to all the points visible to serve as checks upon their determination from other points furnishing directions for good intersections. The survey then proceeds as usual.

It is well at the beginning of work to set off with the declinatoire at some determined point near the middle of the sheet the magnetic meridian, for the purpose of putting the table in approximate position at any station with the declinatoire.

Before finishing the field work it is important, when the sheet has no projection, to provide data for drawing a true north and south line. This is done by drawing from a point upon the sheet, when the table is in position, a line in the vertical plane through Polaris and the point occupied and recording the time of observation. The azimuth of the star at that time being known, a true north and south line can accordingly be set off.

If a small transit instrument is at hand and carefully adjusted for movement in vertical plane, an assistant with a lantern can be located where the vertical plane through Polaris and the point occupied intersects the ground at a distance of half a mile or more from the occupied station. When the assistant is in position a stake is there driven, the direction to which, from the point occupied, may be determined by daylight.

If, in the absence of a transit, the alidade has not vertical range sufficient to reach Polaris, an illuminated plumb line may be used for the alignment.

NOTES ON TOPOGRAPHICAL SURVEYS IN ITALY.

[Presented by Assistant D. B. Wainwright.]

The general topographical survey of Italy is carried on under the War Department, by the Military Geographical Institute.

The officers are selected from the general staff (état major), military engineers, artillery, cavalry, and infantry. A certain number of enlisted men are also employed.

The principal business of the Institute is the execution of all geodetic

and topographic works necessary to obtain the data for the construction of the topographic and chorographic maps of Italy, and those for military and other public services.

The triangulation is constantly two years in advance of the topography. The triangles are nearly equilateral.

The field sheets (scales 50000 and 25000) from the hands of the topographer are reduced and drawn on the scale of 75000 for the production of the final sheets, scale 100000.

The topographical and drawing divisions are both divided into four sections, based on skill and proficiency, with increase of pay according to term of service. The officers receive commutation of rations while in the field, and have their traveling expenses paid.

The field work is entirely done by means of the plane table. A field party consists of a captain of the general staff in charge, with from five to eight topographers (divided among lieutenants of infantry and general service men). Each topographer has two assistants, with stadia rods, by aid of which all horizontal measurements are made. The plane-table sheets, carefully prepared and mounted in advance, are inked in and practically finished in the field. All determined triangulation points are plotted, and altitudes marked also, in advance. These triangulation points are first checked, and the magnetic meridian is then laid down.

A very complete instrument is used with the plane table; the differences in elevation are computed at the station, the distances obtained by stadia measurements, and the contours drawn at 10 metres apart for the 50000 scale, and 5 metres apart for the 25000.

As much of the area now being done by the Institute has been covered by former topographical and cadastral surveys, several topographers may work on a single sheet.

Field minutes in the valley of the Po, vicinity of Florence, Rome, and Naples are drawn to the scale of 25000, and certain seaports at the scale of 10000.

A skilled topographer is expected to cover 50 to 60 square kilometres per month on the scale of 50000, and 20 kilometres per month on the scale of 25000.

Each hundredth metre curve is drawn heavy, and on the published map, scale 100000, the contours, 50 feet apart, alone are expressed.

The finishing of the original field minutes is done by both technical civil assistants and officers. These finished field minutes are converted into finished originals by more skillful draughtsmen, the line work transferred, the lettering, hachuring, and curves added.

The Director states, September 2, 1885, that the average cost per square mile (scale 25000) for field work (triangulation and topography) is $13.12. It must be remembered, however, in considering this small amount, that the salaries and wages paid in Italy are extremely small; and also a great deal of saving was effected by the use of former surveys.

Deville, in his treatise on horizontal photography applied to topographical surveying, states that this method was successfully pursued in mapping some portions of the mountains of Italy. He claims perfect success for the method in Canada, where 1000 square miles have been (up to 1889) surveyed in this manner; and says further, that its failure in other countries is due both to the use of too large scales, and to attempt to map areas having too little relief, as it is only adapted to mountainous regions.

I have been unable to obtain Paganini's treatise on the subject, which gives the results obtained in Italy.

These notes are abstracts from papers by Wheeler, Derrécagaix, and Deville.

NOTES ON SURVEYS OF ENGLAND AND FRANCE.

[Presented by Assistant W. C. Hodgkins.]

PREFATORY NOTE.

It should be borne in mind that, except in Great Britain and Ireland (where all official surveys are consolidated into one organization), there exists in every European country, so far as I can ascertain, a cadastral survey on a large scale, generally from 1–2500 to 1–4000, made for purposes of taxation, and thus furnishing, in advance of a topographical survey, detailed information in regard to all the subdivisions of the country. The fieldwork of the topographer is therefore comparatively simple. He has only to run out by traverse the roads and streams and to sketch the hill forms, all the minute and laborious work of plotting details being saved him.

GREAT BRITAIN.

The cadastral or ordnance survey of the United Kingdom is a wonderfully exact and elaborate work. In all its various processes it appears to aim at absolute certainty of results.

It is not necessary to detail here the preliminary processes of the survey, the astronomical and geodetic work, etc. Confining attention to the fieldwork of the topographical survey, it may be described as follows:

The triangulation having been completed (the sides of the tertiary triangles averaging $1\frac{1}{2}$ miles in length) the rest of the detail work is done entirely by the chain.

The triangle sides are first gone over with the chain, all objects passed between the points being determined by offsets if necessary. The error of chaining must not exceed 2 links in 1000 or 1–500 of the length.

These chained lines furnish means to break the triangles up into still smaller ones by lines run between marked points on the first lines; and this process of subdivision is continued until all objects of detail are determined, including single or detached clumps of trees in the country, and in the city or town even the lamp-posts on the streets.

All of this work is plotted on a large scale, 1–500 for the cities and towns and 1–2500 for the rest of the country. It is afterward examined in the field and any accidental omissions are supplied. The elevations above mean tide, based upon standard level lines previously run, are placed upon the map, and in certain cases contours are run out.

The system followed is to stake out the course of the curve and then to run it out with compass and chain. In this way are run the 50, 100, 200, 300, etc., up to 1000, then every 250 feet up to 2500.

Intermediate forms are sketched on the ground after the curves run out have been plotted.

The published maps on smaller scales are obtained by photographic reduction, from the 1–2500 scale plotting.

In England the plane table does not seem to be used at all, but in the survey of India it is used to some extent for sketching details.

There does not seem to be much in the methods in vogue in the English surveys that would be of utility in rapid surveys of wild country or even in that which is well settled, unless very elaborate work were needed.

FRANCE.

The Dépôt de la Guerre was in its origin, in 1688, only a depot for documents collected in the archives of the War Department and relating particularly to history and military operations.

In 1761, the Depot of Charts and Plans was joined to it and enriched it with a valuable collection composed principally of topographic works, both printed and manuscript, executed by the engineers of the camps and armies during the reigns of Louis XIV and Louis XV. It was not until 1793, when the national convention intrusted to it the task of completing and retouching the plates of Cassini's great map that the Dépôt de la Guerre became an establishment for producing maps, and at that same time a school of topographical engraving was founded which has existed ever since.

For a long time the Dépôt de la Guerre held an independent position. In 1845, only, it was made part of the central administration and formed, up to 1871, a division of the War Department.

When the general staff of the minister was created the division of the dépôt was attached to the new organization.

Finally in 1887, the Dépôt de la Guerre was abolished and was replaced by the Geographic Service.

To the Geographic Service are intrusted all the operations of geodesy, of topography, and of cartography needed by the army in time of peace

Notes on topographical surveys in Europe.

as well as in time of war. It, further, investigates the improvements which may be possible in methods now in use.

The service is organized in five sections, as follows:

(1) Geodesy.
(2) Precise surveys.
(3) Topography.
(4) Cartography.
(5) Accounts.

The section of geodesy has charge of all work coming under that head and which need not be here enumerated.

The section of precise surveys executes large scale topographic work requiring mathematical exactness. This is a special duty directly connected with the construction of defensive military works. These surveys, moreover, constitute a basis for those which may some day be undertaken, should the constantly growing needs of the public service require the production of a new map.

The section of topography makes surveys upon the ground and prepares new maps for general use. It makes use of the geodetic operations to furnish a basis for its topographic network, to determine the relief of the ground, and to represent with exactness the details which ought to appear on the various projections. The thankless and difficult task of keeping the general staff map up to date by means of annual revisions also belongs to this section; also the surveys of Algeria and the preparation of foreign and colonial maps.

The official surveys of France are conducted under the War Department by the "Service Géographique de l'Armée."

These surveys are divided into two principal classes:

(*a*) Precise surveys.
(*b*) Topographic surveys.

Precise surveys.—This term in French usage seems to be applied to work on which much detail is shown and a certain precision is required, without necessarily implying that all the data given is exactly correct. At first the work done under this head was upon the scales of 1–2000 and 1–5000, and was restricted to the immediate vicinity of fortified places. As the extent of ground surveyed has increased, the scale has been diminished and the methods of work modified. At present most of this class of work is done on 1–10000, except in mountainous country, where 1–20000 is used.

Methods of work on 1–10000 scale.—The work on the ground consists of two parts:

The first part consists of the establishment of a general outline obtained by lines from triangulation points and by traverses along the side of polygons, following generally the roads and other means of communication. Along these roads connection is made at numerous

points with bench marks established by precise levels. In this way a network is obtained from 10 to 16 kilometres on a side and divided into small polygons. On the perimeter of these polygons are determined, by the aid of the tachymeter, the geographical positions and heights of a series of marked points, generally about 200 metres apart. This preliminary work is done with leveling compasses or with tachymeters which give angles to the nearest minute. The results of this first work are plotted upon the plane table sheet, together with a reduction to scale of the cadastral surveys.

The second part of the field work consists in revising the plotting of the detail reduced from the cadastral work and of drawing in the horizontal contours at intervals of 5 metres. Details are put in upon the plane table oriented by compass, using a special form of alidade with an attachment for rapid measurement of slopes. Pacing is resorted to for the measurement of distances when the details are not very important. In the plotting it is required that the traverses shall close within half a milimetre and the leveling within four-tenths of a metre. In the hill drawing on the plane-table sheet, traverses are largely used and points are added by radiation from stations. The curves are carefully drawn and records kept of all measures of vertical angles.

The above method is used in all sections not too much broken. It has even been employed in the Vosges and Jura Mountains, but had to be abandoned in high mountain regions. There, indeed, the reduction of the scale demanded the change. The steepness of the slopes made it useless to attempt the delineation of curves with sogreat a precision. Besides, as the work left the valleys, the running of traverses with the tachymeter became more laborious and lost exactness. It was then necessary to resort to more facile methods which still give a sufficient precision. This method has been followed since 1885 for surveys in Savoy and Dauphiné, the original sheets being on 1–20000.

Surveys on 1–20000.—As in surveys on 1–10000, the first step is the development of the general scheme, obtained by tachymetric traverses depending upon the stations of the triangulation. These traverses are almost always run in the bottoms of the valleys on account of the necessity of following routes which do not present too formidable slopes.

The circuits of traverses in the scheme increase in length on account of the scarcity of routes of communication and of the difficulty of working over them. The traverse scheme then proves insufficient, and it is necessary, in order to complete the preparation of the sheet, to introduce a new operation, consisting of the establishment of a graphical triangulation, starting from broken bases formed by parts of the traverses. This is accomplished by occupying the stations of the traverse and then determining by intersection all the objects which form natural or artificial signals.

The graphic triangulation is made with plane tables mounted on a ball and socket joint formed of a segment of a sphere, using large-

sized eclimetre rules. The slopes are taken during the traverse work by means of the tachymeter. All of this work is plotted upon the plane table sheet. The detail work is always done directly upon the plane table, oriented by compass; but little traverse work is done. The positions and elevations are determined by the plane table with sufficient exactness.

The surveys of Algeria are based upon a geodetic triangulation connected with Spain on one hand and with Italy on the other.

The field work is done on 1–40000.

Heights refer to the mean level of the Mediterranean. Wherever cadastral surveys exist they are reduced to 1–40000 and transferred to the plane table sheets, upon which the triangulation points have already been plotted.

The field work is done chiefly with the compass provided with telescope and vertical arc. The barometer is also used for elevations. In ordinary country discrepancies of heights should not exceed 2 metres, in mountainous country, 4 metres.

The hill drawing is begun at the most elevated points and is carried downward. From 4 to 12 points in each square kilometre are determined in elevation.

Where the compass can not be used on account of local attraction the plane table is used.

South Algeria is surveyed on 1–100000 with the plane table oriented by compass, and with heights determined by aneroid barometer.

METHODS OF TOPOGRAPHICAL SURVEYS IN GERMANY, AUSTRIA, AND SWITZERLAND.

[Presented by Assistant J. A. Flemer.]

A—GERMANY.

The oldest military reconnaissances were merely sketched, the distances being obtained by the time it took a drilled infantryman to march over the required line without accoutrements or baggage. A Prussian soldier was supposed to cover 5.5 kilometres per hour in a level country. (The French assume that an infantryman will take 11 to 12 minutes to march over a distance of 1 kilometre, or will cover 5.2 kilometres per hour.)

With the aid of the plane table and the theodolite a gradual improvement has been established in this direction and the topographical maps of the Prussian general staff of the present time are ranked among the best productions of the topographic art.

Since 1871 the general staffs of Bavaria, Würtemberg and Baden have joined in the operations of the Prussian general staff. The surveys of the German Government can be grouped into four classes:

(1) Military Topographical Surveys.
(2) Cadastral Surveys (for taxation).
(3) Preliminary Surveys for Engineering Purposes.
(4) Scientific Geodetic Surveys.

Bavaria was the first of the southern German states to make a general topographic and a cadastral survey of the entire kingdom. This first survey was made in the first quarter of the present century and it was based upon a system of rectangular coördinates, invented and laid out by Soldner. This system of coördinates was subsequently extended over Würtemberg, Baden and Hessen.

Baden was the first of the German states to make a general topographical survey and to use *contours* for the delineation of the terrene (1825–1846). The new topographic map of Baden (1874) shows contours in 10 metres vertical interval; it is published in 170 sheets on a scale of 1–25000 and printed from copper plates in three colors. This map is based upon:

(1) The old topographical survey.
(2) Forestry and Cadastral maps.
(3) Resurveys.

The old maps were taken into the field and compared with the terrene; if small corrections only were needed, these were sketched in; larger corrections were made by special resurveys.

Military topography.—Under this heading we can distinguish two classes:

(1) Topographical surveys, made as such, and independently carried out.
(2) Topographical surveys based upon cadastral surveys.

The former have been chiefly practiced in Prussia, Saxony and Baden.

The latter (based upon cadastral surveys) are represented by the surveys of Bavaria and Würtemberg.

The general topographical maps ("General—Stabs—Karten") of all the German states show a remarkable uniformity in their general appearance in regard to general detail and accuracy. Germany has spent great sums of money, much skill and labor in the work of revision, and is continually improving the maps and bringing them up to date.

The process of a general topographical survey of a country passes through three stages:

(1) Triangulation.
(2) Actual topography.
(3) Cartography.

Triangulation.—Theodolite-polygons originated along the Rhine under French *regime*, and the effectiveness and accuracy of the trigonometric methods were soon generally recognized and now are used throughout.

Methods of topographical surveys in Europe.

(Hanoverian Triangulation, by Gauss; Triangulation of Lauenburg, by Schumacher; the Prussian, by Bessel and Baeyer; the Bavarian, by Soldner and Schwerd; the triangulation of Würtemberg, by Bohnenberger; the Hessian, by Eckhardt, etc.)

In Austria, Prussia, and Baden the triangulations were carried out by the general staffs.

The German primary triangulation has triangle sides from 10 to 100 miles in length. The base lines are measured with the highest accuracy attainable. The latitude and longitude of at least one point in each triangle have been determined by careful astronomical observations, and also the azimuth of at least one side of every primary triangle.

The network of primary triangulation is subdivided into triangles of the second, third, fourth, and fifth order. All of the points are well marked and described, and they form the initial stations for the topographer, from whence all other points are determined, with aid of the plane table; at least, such is the custom in Germany, Austria, and Switzerland.

The ordinary plane-table sheet in Germany (17 by 20 inches) contains from 20 to 40 triangulation points for the use of the topographer. During the work of the triangulation, both spirit and trigonometric level operations are carried on, and the elevations of all triangulation points are determined by these two methods, while the elevations of all subsequent points, to be used for the delineation of the terrene are made by alidade and plane table, or in wooded sections by barometric leveling.

The barometers, in recent years, have been greatly improved and they are excellent for this purpose, the mean error being comparatively small.

In Bavaria and Austria barometric leveling has become a favorite method for topographical delineations of the terrene.

In the preliminary governmental topographic surveys for engineering purposes, in Germany, it is considered too expensive to use the level, and only for the final location of railroads, canals, roads, etc., the relief and contours along the line are determined by spirit leveling and for all general or preliminary purposes the terrene is delineated by aid of barometric leveling (aneroids).

In the southern states of Germany, in Switzerland and in Austria, the "method of barometric measurements with corresponding observations" is employed almost throughout for all general topographical surveys, lines of spirit levels being run along main roads, railroads, canals and rivers.

The aneroids chiefly used for leveling purposes are: Vidi-Naudet's aneroid (made by Goldschmidt in Zürich) with microscopical reading, and J. H. Reitz's improved aneroid, made by Deutschlein in Hamburg (known as Reitz-Deutschlein's aneroid) which has also a microscope for

direct reading, and it is claimed that 0.001 millimetre can be read off with ease. (Zeitschr. f. Vermessungswesen, 1874.)

According to tests made by Prof. Koppe with Naudet's aneroid, the diameter of circular scale being 12 centimetres, and based upon 248 observations on points originally determined by precise leveling, the probable error proved to be 1.1 metres. The direct comparisons gave the following results:

114 errors were found to be from 0 to 1 metre.
70 errors were found to be from 1 metre to 2 metres.
47 errors were found to be from 2 metres to 3 metres.
14 errors were found to be from 3 metres to 4 metres.
3 errors were found to be from 4 metres to 5 metres.

The greatest error observed had been 4.4 metres. These tests were made under conditions similar to those which are met with in general traverse work.

Schoder (Hülfstabellen zu barometrischen Höhenmessungen) gives the probable error of Naudet's aneroid (12 centimetres), based upon forty seven observations, as 0.94 metre for differences of elevations lying within the range of 0 to 113 metres.

If we remember that the errors are not accumulative and adhere only to single points, not to be transmitted to subsequent points, this error may not be too great for general topographical purposes.

The elevation of every bench mark (determined by spirit level or vertical angle) which is redetermined by the aneroid will serve as the datum for all subsequent points, determined by aneroids, until the next bench mark is reached. In other words, all points which have been determined by aneroid readings will be referred to the last bench mark checked upon.

Rühlmann maintains that the horizontal distance between station and field barometer is not to exceed 37.5 kilometres.

Bauernfeind gives 60 to 75 kilometres as the limit in lowlands, and no ridge of hills should intervene between the corresponding barometer stations.

The station barometer is brought up to the advanced field barometer every night, and for this reason alone it will not often occur that distances over 30 to 40 kilometres will separate the barometers. Generally speaking, the cost of aneroid-leveling is low.

In 1873 two engineers with one assistant made a survey of 1,920 hectares for the Rhenish railroad, through a very broken country in fifty-nine days. The scale of survey was 1–10000, the levels were taken with aneroids. After the fieldwork had been completed, the elevations calculated and tabulated, the map was drawn, based upon Prussian cadastral maps, and the contours drawn in, in vertical intervals of 5 and 1 metres. The office work took twenty-eight days, including the location of the proposed railroad.

Methods of topographical surveys in Europe.

For final or special surveys for engineering purposes the scale is generally 1–2500 with curves in 1, 2, and, in very steep grades, 5 metre intervals. Whenever the character of ground requires it, subsurveys are made on scale 1–1000, or even 1–500.

Formerly every State had a separate datum plane or point of reference, to which the elevations of topographical surveys were referred. After the general topographical surveys, however, had been extended over several States it was found that the elevations and contours of adjoining States showed discrepancies, which in some instances were too great to be disregarded even for general purposes. It proved that none of the States had used the same plane for mean sea level, although all were referred to "the sea."

A number of lines of precise levels had demonstrated the fact that the mean level of the sea was different in different seaports (within several decimetres) and the central directory of the Prussian surveys decided to assume a datum plane which would satisfy the greatest number of the various datum planes which had been in vogue throughout the Empire, and after having decided upon such a plane of reference, to enforce the rule that in all topographical surveys the elevations and contours are to be referred to said plane.

Northern Germany had used the "mean sea level" at Amsterdam as datum plane, and it was found that the zero mark of the tide gauge at Amsterdam was in that plane, which satisfied the greatest number of the different datum planes heretofore used in different parts of Germany, by being very near the mean plane for all.

Subsequently this zero mark, termed "normal null," was taken as the initial point upon which all levels in Germany are to be referred and a point marked at the observatory at Berlin as being "37 metres above normal null" is the initial bench mark for all Prussian surveys. A net of precise levels extending from Memel to Basel in one direction, and from Cologne to Breslau in another direction, has been established by the German general staff, thus locating a large number of reference points throughout the Empire. The elevations and contours shown on the recently published topographical maps have been corrected with reference to "normal null." In Baden, for instance, the old data had to be reduced 2 metres to bring them down to the new datum plane ("normal null").

At the present time this plane of reference (normal null) is used throughout Germany, and the value of the uniformity thus established is considered as greatly outweighing the cost of the work.

There are three classes of leveling operations in Germany. Ranged in their order of accuracy they are:

(1) Spirit leveling.

(2) Trigonometric leveling.

(3) Barometric leveling.

For topographical surveys we find the plane table with distance-reading alidade and the tachymetric plane table chiefly in use. The reasons assigned therefor are:

(1) Its great effectiveness for the delineation of the terrene.

(2) Small damage to crops in gardens and fields.

(3) Saving of time by measuring distances to points only (and plotting their positions) which are cardinal points, omitting all secondary or auxiliary points.

(4) Little chance of omission of important features of the terrene or details.

In different parts of Germany we frequently find the plane table supplemented by theodolite and stadia (tachéomètre) measurements with compass and direct lineal measurements, with lineal measurements and offsets, etc.

Generally speaking, however, the plane table combined with spirit or even barometric leveling, is considered the most efficient method of making a well-developed topographical survey.

Traverse lines through forests are frequently run with tachymeter, theodolite, and compass, in combination with telemeter, steel tape, or even with Rud. Wittmann's measuring wheel. (Zeitschrift d. Oestr. Ing.-u. Arch.-Vereins, 1875.)

One well-trained topographical party ("general staff") will, on an average, survey about 0·3 to 0·5 square miles per day with the plane table, on 1–25 000 scale.

The tachymetric plane table method has gained many advocates in recent years, especially for the topographical surveys of Austria and northern Germany. One skilled topographer, with assistant, can determine 600 points with the tachymeter in a working day of ten hours.

Cadastral surveys.—These are based upon the measuring of a planimetric base line and lineal measurements along offsets, generally. In the southern states of Germany the plane table is extensively used for these surveys, while the northern states give preference to the polygonic methods using tachymeters, theodolites, compass, etc.

The cadastral maps of Bavaria are lithographed on 1–5 000 scale, those of Würtemberg on 1–2 500 scale; Duchy of Brunswick, 1–3 000 scale for general maps and 1–1 500 for towns and villages.

The city of Hanover has been surveyed and mapped in quite an elaborate manner:

Scale of general map of city	1–5 000
33 sheets showing the streets	1–1 250
13 sheets of the 13 wards of the city, into which the city had been subdivided for this survey	1–1 250
13 sheets of the same 13 sections	1–5 000
Maps of all city lots and improvements	1–125
Outlines of buildings of all improved city lots, including descriptions of building material and estimated value of improvements	1–125

Methods of topographical surveys in Europe.

The city of Berlin was surveyed on a scale of 1–250. The published plans are printed from copper plates on scale of 1–1 000. The plans are scratched into "gelatin paper," the scratches filled with graphite dust and transferred to a thin wax coating upon the copper plates. After having been engraved on copper these plans are transferred to stone (by Straube in Berlin) in order to get prints from these, avoiding the distortion caused by wetting the paper from copper prints. An extensive system of precise leveling was carried out upon which the new survey of Berlin has been based. In 1886 over 4 000 bench-marks had been established on iron bolts (inserted into walls and buildings) specially designed for this purpose.

The permissible error for level lines is given in condensed form for the new Berlin survey as follows:

2 millimetres, error for lengths up to 50 metres.
4 millimetres, error for lengths from 100 to 250 metres.
6 millimetres, error for lengths from 500 to 750 metres.
8 millimetres, error for lengths from 1 000 to 1 500 metres.
10 millimetres, error for lengths from 2 000 to 2 500 metres.
15 millimetres, error for lengths from 6 000 to 7 000 metres.
20 millimetres, error for lengths from 11 000 to 12 000 metres.

In the city survey of Hamburg the aneroid of Reitz-Deutschlein was used (in wooden case and with microscopical reading) and curves run with this instrument in a vertical interval of 1 metre. (With these instruments interpolations, within half an hour's time and within a range of difference in elevation up to 80 metres, have been made with a mean error of ± 0·4 metre.) (Zeitschrift für Vermessungswesen, 1873).

Photogrammetry has been practiced by the Germans for military purposes chiefly, although a special chair is maintained at the royal technical high school at Charlottenburg, near Berlin, for the study of this branch of topographical surveying. It is recommended for hilly, steep-cliffed regions and for the study of lateral changes in beaches and shore lines generally. The Germans also use a number of reflecting distance-measuring instruments in cases where it is difficult to employ rodmen. The following list comprises the most popular ones of this class of instruments:

The engymeter of Fallon (Austria).
Distance measurer of Adri & Son (Germany).
Distance measurer of Tavernier Gravet (France and Germany).
Distance measurer of Fortin (France and Germany).
Distance measurer of Ceribotani (Italy and Germany).

Ceribotani's distance measurer of 1 metre base gave for distances of:

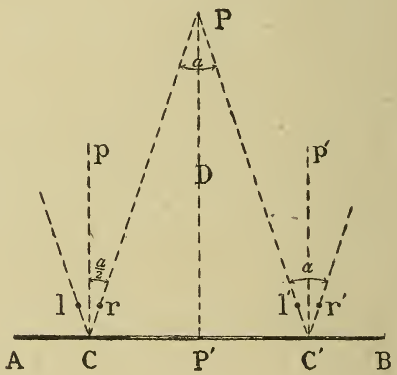
150 metres an error of 0·2 metres.
300 metres an error of 0·8 metres.
600 metres an error of 3·2 metres.
1 000 metres an error of 10·7 metres.
2 000 metres an error of 42·7 metres.
3 000 metres an error of 96·0 metres.

Oertel & Son, in Munich, have constructed a distance-measuring telescope which is highly recommended:

A B is a rule over which a telescope (with two vertical wires) can slide in either direction, the optical axis of the telescope always remaining at right angles to A B.

The distance D of point P from station A B is to be determined.

The telescope is clamped on the zero mark C of rule A B, and the whole instrument moved to the right or left until the right-hand wire r bisects P. The rule A B is now held in this position and the telescope moved towards B until the point P is bisected by the left-hand wire l.



The angle α is given for every instrument.

C P′ = P′ C′ can be read off or measured on AB.

$$\measuredangle \text{P C P}' = 90^\circ - \frac{\alpha}{2}$$

$$tg\frac{\alpha}{2} = \frac{\text{C P}'}{\text{D}} = \frac{\text{C C}'}{2\text{ D}}$$

$$\text{D} = \frac{\text{C C}'}{2\,tg\frac{\alpha}{2}}$$

B.—AUSTRIA.

The new special topographical (military) survey of Austria which was begun in 1869 in Tyrol, is published on a scale of 1–75000.

The field sheets were plotted on a scale of 1–25000 and the survey is chiefly based upon the cadastral survey of the Empire. In the mountainous regions, each working section (four of which make one special map sheet of 30 minutes length and 15 minutes width) contains on an average 1 600 points of elevation (bench marks), which number is reduced for the more level parts of the country, where one sheet contains

about 400 of such points. These points of elevation are based upon level-lines of precision, (13 800 kilometres of which had been run at the end of 1884, giving 2 417 primary bench marks) and upon data furnished by the military and cadastral triangulation. Each working section had on an average eight or nine elevations of precision or primary bench marks, upon which the number mentioned above (400 to 1 600) was based. These subsequent points were established, partly trigonometrically, partly barometrically with Naudet's aneroid. The contours are given for intervals of 100 metres, where the grade is over 10° and in 20 metre intervals for grades less than 10°.

Based upon this survey on field scale of 1–25000, the special topographical map of 715 sheets was published on 1–75000 scale. (The entire map would cover an area of 133 square metres.)

The published sheets are arranged so that the east and west margins are meridians in equidistant intervals of 30 minutes each.

The top and bottom margins are parallels in equidistant intervals of 15 minutes each. The projection used is the same as in Prussia, the polyëder projection. The total map extends from 42° to 51° 15′ latitude and from 27° to 44° 30′ longitude. The zones are counted from north to south (1 to 37) and the columns from west to east (I to XXXV). This survey was finished in April, 1885.

This work has been published by heliogravure.

The cadastral survey upon which this topographical survey was based had for its basis a triangulation and plane table survey, and it was made in three scales for different localities: 1–12500, 1–6250, and 1–3125.

With the aid of this cadastral survey and level data, obtained as mentioned above, and by combining the plane table with direct measurements the terrene was sketched in on the 1–25000 scale field sheets.

One topographical party (military) averaged 0·9 square mile per day on scale 1–25000 and 0·4 square mile on scale 1–12500. Goldschmidt's aneroid is extensively used for running out contours in Austria, the rodman carrying the aneroid, by means of which he adjusts his position, before holding his rod up on the critical points of the contour.

C.—SWITZERLAND.

The methods generally used for topographical surveys in this country have been alluded to in the preceding pages.

The original sheets of the topographic atlas of Switzerland for rolling country are on 1–25000 scale; for mountainous country, 1–50000 scale.

The general maps of the same regions are published on scales of 1–100000 and 1–500000, respectively.

The Dufour atlas, in twenty-five sheets, is published on 1–100000 scale; the same has been reduced to a wall map in four sheets of 1–250000 scale.

In the retrospection of the foregoing report I would respectfully suggest a consideration of the following:

(1) The polar method as originally devised by Lehmann and improved by combining the telemeter with the plane table (Reichenbach's telemeter, first described in Dingler's Polytechnic Journal of 1850 by G. Decher) has now almost been supplanted by the tachymetric method.

This method (tachéometric) was first employed by French engineers and has been in use since 1860. Tachéomètre (in Germany tachygraphometer or simply tachymeter) avoids both the reduction of telemeter reading to the horizon, and the calculation of the elevations, based on the vertical angle and reduced telemeter-reading (with aid of formula or tables), inasmuch as the tachymeter performs these calculations automatically. The use of the new tachymetric plane-table also dispenses with the use of dividers for plotting distances. The fact that this instrument has superseded the plane-table with distance-reading alidade throughout Europe would suggest a closer inspection and investigation of the merits of this instrument with a view of increasing the rapidity of topographical surveys.

(2) The marked improvements in the construction of aneroid barometers in recent years (invented by Vidi, 1847, and constructed by Bourdon in 1848; improved by Naudet; by Goldschmidt, in Zürich, 1859; by Reitz and Deutschlein in Hamburg; by Prof. Weilmann in Zürich, etc.) have justified their use in leveling operations made for topographical purposes.

The method of barometric determination of elevations for the plotting of the terrene by employing aneroids, has chiefly been perfected in Austria (in a measure also in the southern states of Germany and England) where Vidi-Naudet's aneroid is principally used. In Germany, Goldschmidt's (self-registering) and Reitz-Deutschlein's aneroids are preferred for topographical purposes. In Austria contours have been run out (on calm and cloudy days) by placing the rodman on a contour and noting the reading of the aneroid. The rodman then proceeds to follow the contour out, selecting the next characteristic change in its course, and moving up or down hill until the aneroid gives the same reading as at the first point. He then holds the telemetre in this new point of the contour until the observer at the plane-table has read the distance and waved him off, whereupon he selects the next point on the contour in the same manner, and so on.

If the aneroids are sufficiently trustworthy to give the elevations within a limit of error of one metre (Schoder, in his Hülfstabellen zu barometrischen Höhenmessungen, Stuttgart, 1874, has given the mean error for the elevations of 47 points lying within a vertical range of 113 metres as 0·94 metres) the trial of these instruments seems advisable for traverse work through wooded sections and also for rapid general topographical surveys.

NOTES ON EUROPEAN TOPOGRAPHIC MAPS, FROM THE REPORT BY GEN. DERRECAGAIX TO THE INTERNATIONAL GEOGRAPHICAL CONGRESS HELD AT PARIS IN 1889.

[Presented by Assistant W. C. Hodgkins.]

BELGIUM.

Independent Belgian surveys were not instituted till 1831. In that year, on January 26, the Dépôt de la Guerre was established. In 1878 its title was changed to that of Cartographic Institute.

The maps of Belgium are prepared on the three scales of 1–20000, 1–40000, and 1–160000. The maps on the last two scales are derived from the first.

At one time a map on 1–80000 was proposed and was actually begun. This would have harmonized with the maps of France and of Rhenish Prussia and Westphalia on the same scale. But the latter maps having been supplanted by the 1–100000 map of the German Empire, one of the reasons for the existence of an 80000th map of Belgium disappeared. Besides, the map on 1–40000 gave all principal details and that on 1–160000 was excellent for more general purposes. It was found that the 80000 would often show too much or not enough detail, and as from the military point of view it did not offer advantages proportional to its cost, it was decided to abandon it.

There is also a map on 1–10000, which is simply an enlargement of the surveys on 1–20000.

The field work on 1–20000 is based upon an old triangulation, revised and completed since 1831. The triangulation was completely finished in 1866, and comprises 4 182 triangles of the three orders, in an area of 29 455 square kilometres. It is connected with the work of the neighboring countries. The cadastral plans reduced to 1–20000 serve as a base for the preparation of the plane-table sheets.

The planimetry was verified and completed upon the ground.

The study of the relief was very complete, more so than in any country of Europe with the exception of some provinces of Holland.

The contour interval is one metre, except on the right bank of the Meuse, where it is five metres. Heights refer to mean low water of spring tides at Ostend.

DENMARK.

The general staff of the army has charge of the surveys. Decimal scales are used, but not the metric system.

Horizontal contours for the representation of relief were first used in Denmark.

The work began about 1830. The triangulation was finished in 1871. It is connected on the north with the Norwegian triangulation and on the south with the Prussian.

The geometric leveling of the first and second orders was begun in 1874 and, favored by the slight relief of the ground, has been carried on with especial care. The number of elevations determined varies from 150 to 260 per square mile.

The topographical surveys, begun in 1830, are invariably executed on 1–20000, by the aid of pantographic reductions of the land (or cadastral) surveys on 1–4000.

These reductions are fitted to a reduction of the geodetic triangulation; then completed and revised on the ground.

The topographer occupies each of the stations of the precise levels and determines by radiation the positions and elevations of enough points to insure the exact drawing of the curves, the vertical interval of which is 5 Danish feet (1·57 metres = 5·15 feet United States standard). Upon slopes above 14° the interval is 40 feet.

The work is published on 1–20000 in photolith. Size of sheets, 0·38 by 0·314 metres. It is also published on 1–40000 and 1–80000, these sheets being engraved on copper in excellent style.

The engraving is done with Porensen's "chalcograph," a kind of pantograph which has a finely pointed diamond upon the tracing point. The reduction is thus done directly upon the copper and is afterwards touched up by hand. The engraving is too fine for good effect.

HOLLAND.

The chief characteristic of the Dutch surveys seems to be the great minuteness with which all details are shown.

The relief is in general slight, and therefore single houses can be shown even on 1–200000.

The older surveys were made on 1–25000 and published on 1–50000.

Since 1874 a new survey of the rivers on 1–5000 has been in progress.

PORTUGAL.

Surveys are made on 1–50000 and 1–100000. Published sheets on 1–100000 and 1–500000.

The work is of rather low grade.

Curves are shown at intervals of 25 metres on the 100000 and of 100 metres on the 500000.

ROUMANIA.

The triangulation of Moldavia is connected with the Russian scheme in Bessarabia and with that executed by the Austrians in Wallachia in 1855–'56–'57, also with the Transylvanian triangulation.

The first topography done was in the Dobrudscha, which, being almost flat and nearly uninhabited, offered a favorable field for a first attempt.

This survey was finished in 1886 and the more difficult work in Moldavia was then taken up, and 80 sheets were done there in 1887 and

Notes on European Topographic Maps from a report by Gen. Derrécagaix.

1888. The force consisted of one major, 1 captain, and 32 lieutenants. The work was done on 1–50000 in the Dobrudscha and on 1–100000 in Moldavia. Relief is shown by contours.

The plane table is used, with a German pattern of telescopic alidade. The compass is also used.

The published charts are lithographs in colors, on 1–200000. Projected roads are shown by dotted lines. Telegraph lines are shown.

Few elevations are given; averaging one in 40 square kilometres.

RUSSIA.

A corps of military topographers was established in 1822 and completely organized in 1826. In 1866 the corps was re-organized, and consisted of 6 generals, 33 superior officers, 156 officers, 170 topographers, 236 topographers ranking as corporals, 42 students. The appropriation was $136 000.

In 1877 the section of military topography was again re-organized with a main office at St. Petersburg. In 1887 this service included 10 generals, 24 officers of the general staff, 154 officers, 223 topographers, and to supply vacancies, 12 officers of infantry, 42 assistant topographers, 2 civil employés, a total of 447. The law requires a force of not less than 367 persons.

The field work is done on 1–21000 in the settled districts and on 1–42000 in the northern provinces and on the great steppes of the east.

The compensation of the officers ranges from $4 240 for chiefs of sections to $1 020 for assistant topographers.

An academy or training school is connected with the service.

During the war between Russia and Turkey, the corps made surveys of the country traversed by the Russian army, and prepared a map on 1–126000. In three years, 180 topographers determined 51 astronomical stations, measured 6 base lines, completed a triangulation of 1 287 stations, surveyed 46 900 square miles and made a reconnaissance of 5 500 more. The bases were from 3 to 6 kilometres long, and were measured with wooden rods. The triangulation was connected with the Russian and Austrian systems.

In the settled districts the surveys were on 1–42000, elsewhere on 1–84000. Relief was represented by contours at intervals of 8 metres, 10 metres, and sometimes more. In this way the survey of the Balkans was done in less than three years. This work corresponds, on an average, to the survey of a strip of country 238 by 38 miles, each year. The cost was very great, but the results were also remarkable.

In maps of Russia the scales are based on the number of versts to the inch.

The inch and foot are the same as the English.

The sagene equals 7 feet = 2·133 metres and is used for heights.

The verst = 500 sagenes = 1066·78 metres = 3 500 feet.

The principal maps are:

(1) The chart on the scale of 10 versts to the inch (1–420000) of European Russia in 154 sheets, and

(2) The topographic map on the scale of 3 versts to the inch (1–126000) of European Russia in 972 sheets and 59 sheets for Poland. There is also a map of the province of Moscow on 1–84000 in 40 sheets, a chart of Turkey in Asia on 1–840000, a military map of Turkestan on 1–680000, and in general maps called provincial on 1–210000.

The triangulation has extended over a long series of years and is of varying degees of precision.

Precise levels were begun in 1873. They generally follow the railways. They appear to be largely dependent upon vertical angles.

Field work was at first done on 1–146000 and 1–105600. In 1844, the scale of 1–42000 was adopted and later still 1–21000 for cultivated territory. Relief was represented by hachures.

In 1870, when the greater part of the western provinces was already surveyed, the form of the work was changed. The use of colors was rejected and a greater number of bench marks being furnished the topographers, the terrene was ordered to be represented by contours with intervals of 2 sagenes = 14 feet.

The surveys are now going on in the northwestern provinces, where in the last season 34 topographers surveyed 3 778 square versts on 1–21000 at a cost of 67 478 roubles (1 658 square miles for $53 982, or $32·56 per square mile). Each topographer averaged 24 square versts (about 10½ square miles) per month.

Other special surveys were also made on the southwestern frontier. The average cost ot a square verst in European Russia is stated by General Derrécagaix at 17 roubles ($13·60), which would make the average square mile cost $31.

Surveys in Asia have been made on various scales from 1–17000 to 1–84000.

The chart on 1–420000 was begun in 1840, is engraved on copper and is kept up to date. The relief is shown by hachures with vertical light. There is also a lithographic edition in four colors. Each sheet includes 3° 30′ in longitude and 1° 48′ in latitude. Brown is used for the hachures, green for the forests, horizontal blue lines for the marshes, black for all other features. The number of buildings in each town is given on the chart. The map on 1–120000 is also on copper and is printed in black. Occasional elevations are given.

SPAIN.

In Spain, there are two organizations which produce maps. In 1856 the "Comision Militar del Mapa" began a triangulation of the country. In 1865 two divisions were formed, one for geographic work and one for statistics. In 1870 these were united to form the Geographic and Statistical Institute, which is under the direction of the Minister

Notes on European Topographic Maps from a report by Gen. Derrecagaix.

of Agriculture and Public Works. In addition there is the Dépôt de la Guerre, under the direction of the Minister of War and engaged entirely in cartography and military reconnaisances.

The Geographical and Statistical Institute, which was re-organized in 1877, takes charge of the geodesy, the regular topography, the precise levels, the cadastral surveys and records, the legal metric measures, and publications in relation to statistics and meteorology.

The Dépôt de la Guerre has its own map making and printing establishment for the ready production of military maps.

The triangulation of Spain is of a very excellent quality, and is connected with the French work on the north and the Algerian on the south.

The leveling was also done with much care. Precise geometric levels were begun in 1871 and were supplemented by levels of the second order and by a network of traverse lines about 600 metres apart.

Heights are referred to mean level of the sea at Alicante.

Field work is done on 1–25 000 and shows the boundaries of the communes, all streams, means of communication, inhabited places, and culture. In this country, there are cadastral surveys for only a small part of the territory, and the survey is consequently slow. To limit to some extent the amount of work, subdivisions of less than 25 acres are omitted. Contours are drawn in the field at vertical intervals of 10 metres. Published maps are lithographed on 1—50 000, in colors.

SWEDEN AND NORWAY.

The corps of geometrical surveyors formerly had charge of the preparation of geographical charts of the kingdom. Now it is employed only in the publication of the cadastral survey, on the scale of 1–4000.

Ordinary surveys and map making are made by the topographic section of the Swedish general staff. There is also attached to this section an economic and statistical survey of the soil.

The cadastral survey forms the basis of all the others. When it is defective, a survey is made to supply the omissions or to correct the errors.

In Norway, the Geographic Institute of Christiana in charge of a superior officer under the direction of the Secretary of War makes the surveys and publishes the maps.

The triangulation of the two countries has been finished and revised, but is sparse in the northern parts.

Determination of relief rests upon precise levels carried across the country from sea to sea, and furnishing from twenty to twenty-five determined points per square mile.

Surveys are made on three scales, 1–20000 for settled districts and important places, 1—50000 or 1–100000 for the northern regions and high mountains. The land surveys on 1–4000, which form the basis for

the twenty-thousandth work, are not published. The originals are kept in the archives of each province, and copies are deposited in the central office at Stockholm or Christiana.

The principal published maps are those on 1–100000 and on 1–200000. There are also geologic and other general and special maps. All show a great amount of detail, made necessary by the peculiar character of the country. Roads, rivers, and the borders of lakes and seas are colored by hand. Both vertical and horizontal hachures are used to express relief, the former in arable land, the latter in rocky places.

The map of Norway is lithographed in colors. Contours in brown, water and marsh in blue, glaciers in green, the rest in black.

The general map of the two countries on 1–200000 is both engraved and lithographed. It shows nearly as much detail as the one hundred thousandth.

Relief is represented by 34-metre contours.

CONCLUSIONS OF GENERAL DERRÉCAGAIX.

The study of large scale topographic charts has brought out various general results, which may be thus summed up:

In addition to cadastral and tactical maps three general types have been adopted—

(1) Reproductions of the notes of surveys on a large scale, varying from 1–20000 to 1–50000, except in England, where there is a real, leveled cadaster.

(2) A topographic map, most commonly on 1–100000, as in Italy, Switzerland, Germany, Portugal, Sweden and Norway, and Roumania.

(3) A chorographic map on 1–200000, as in Austria, Holland, France, and Sweden and Norway.

From these facts, and recent improvements in methods and instruments, General Derrécagaix deduces the following proposals:

(1) The general use of the metric system to express heights.

(2) Uniformity in conventional signs.

(3) The adoption of a common scale for topographic and chorographic maps, the one hundred thousandth and two hundred thousandth being the best.

(4) The publication of reproductions of large scale surveys.

PHOTOGRAMMETRY—SHORT HISTORICAL REVIEW OF FRENCH AND GERMAN SURVEYS.

[Presented by Assistant J. A. Flemer.]

Regarding a photograph as a geometrically true perspective, photogrammetry will be the art of reconstructing geometrical projections, upon a plane surface of the terrene given and represented in perspective views.

The theoretical, fundamental principles upon which such reconstruc-

tions are primarily based were already known to Lambert, who published a work on perspective as early as 1759.

The French savant, Beautemps-Beaupré, attempted the first practical application of these principles for the use of topography while on a scientific expedition in 1791–1793, when he made perspective drawings of coast regions, and later constructed topographical maps based on these drawings. A map of a part of Van Dieman's Land, and also of the island Santa Cruz, was obtained by him in this manner.

Although Beautemps-Beaupré frequently referred to the feasibility of constructing topographical maps based on this method, the same almost sank into oblivion until M. Laussedat, major in the French army, again took the subject up.

In 1851 he constructed a modified "camera clara," which was superceded in 1858 by the "camera obscura," with additional improvements by Regnault, for surveying purposes.

Laussedat made numerous experiments with Regnault's improved "camera obscura," partly on his own behalf and partly under the auspices of the French ministry of war. His experiments were continued by Javary from 1863–1870.

The first German record on this subject is probably the article published in Horn's Photographic Journal in April, 1863. This article is a description of Laussedat's experiments, as given by him in a meeting of the French Photographic Society, held January 9, 1863.

We find Meydenbaur's first publication on photogrammetry in the June number of the Photographic Journal for 1863 ("Photographische Mittheilungen"), in which he uses the term photometography, which was subsequently changed into photogrammetry.

Pujo and Fourcode published a joint essay in Les Mondes, 1865, on "Goniometrie Photographique."

In the March number of the "Photographische Mittheilungen" for 1866, we find an article by Vogel on the use of Johnson's photographic apparatus for making topographical surveys, in which he shows the construction of vertical and horizontal angles.

Ever since Meydenbaur first became interested in the method of photogrammetry he endeavored to interest private and governmental surveyors in the method.

Jordan and Hauck have also done much to popularize this method in Germany.

Since 1869, photogrammetry was treated both theoretically and practically in the Royal Building Academy (Kgl. Bau Academy) in Berlin, Prussia, in the lectures on geodesy and photography. Several years ago the new Royal Technical High School in Charlottenburg, near Berlin, was completed, and since then a special chair has been maintained there for the purpose of teaching photogrammetry theoretically and practically; at present Dr. Pietsch fills said chair.

The first attempt to make a more extended practical survey with the camera in France was made by Laussedat in 1861, when he mapped a portion of the city of Paris, which work was followed by the photographic survey of the town of Grenoble, under the direction of the French Ministry of War. The area covered by this survey was 0·4 square mile. The field work lasted sixty hours and the office work two months.

Javary's work in this direction closely followed Laussedat's.

In Germany, the first larger attempt was made in 1867, under the direction of the Royal Prussian Ministry of War and Commerce, consisting in a topographical survey of the town of Freiburg, and also an architectural survey of the dome in Freiburg. Field work lasted four days. The area covered about 0·04 square mile. The office work for the construction of the topographical map took three weeks. The drawing of the ground plan, one front and one side elevation of church, took eight days.

During the Franco-Prussian war, photography was called to aid by the German army, and a detachment for field photography was formed to obtain and plot a certain area about Strasburg with the aid of the camera.

This detachment (under direction of Dr. Doergens, now professor of geodesy in Berlin, Techn. High School) made a map, scale 1–2500 of the besieged front of the city. The data obtained by this survey, however, were not utilized, as the city capitulated a few days after the detachment had commenced its work. Some discrepancies were discovered in this survey, which were attributed to defects in the lens of the instrument used.

Jordan, a member of Rohlf's African expedition, 1873–1874, made a good photogrammetric survey of the Oasis Gassr Dachel, in the Libyan Desert. In 1874, Stolze used a Meydenbaur camera-theodolite to make a survey of the ruins of Persepolis and of the temple of Djamâht in Shiraz, Persia.

ASCERTAINING AND REPRESENTING UPON A PLANE SURFACE ANY PORTION OF THE SURFACE OF THE EARTH, BY MEANS OF A PHOTOGRAPHIC PROCESS KNOWN AS "PHOTOGRAMMETRY."

The idea of utilizing the image obtained with a "camera obscura" for a geometrically true representation of terrene or buildings, is probably as old as the camera itself, but the chances of the realization of the idea have become probable only with the improved methods and general progress made in photography during recent years.

Experiments in this direction were notably made, at an early date, in Italy and France; practical results, however, failed to materialize, swing partly to the uncertainty and slowness of the photographic process in general, and partly to the greatly increased efficiency of other surveying instruments and methods.

By mastering photography and combining it with geodetical instru-

ments, the idea of photographical surveying has become a reality, and at this date must be regarded as a subservient factor in modern engineering no longer to be overlooked.

Mr. Meydenbaur, who spent many years in the study of this question, has perfected this idea, and also demonstrated the capabilities of photogrammetry by practical tests which proved the efficiency of this method of topographical surveying. Also in astronomical surveying, photography has led to excellent results.

Photogrammetry being comparatively a recent invention, has not yet attained its height of perfection, and it is susceptible of many improvements, still, notwithstanding the cumbersome nature of the camera-theodolite, compared with other surveying instruments, its use promises great results. Even at its present stage of imperfection, Mr. Meydenbaur has, with no other expedients or help than his camera and an instrument bearer, taken a photographical survey of a valley in a mountainous region in a few hours' time. After a lapse of several weeks he returned to his home, and there constructed a topographical map, based on the photographical data obtained in the field, and a subsequent comparison of his map with another obtained by plotting the results of a trigonometrical survey of the same region by another party, proved the correctness of his work.

Every survey is founded on the determination of horizontal and vertical angles, measured at the ends of a straight line (base line) of a known length. The camera produces an image of the terrene, which is to be surveyed, of the exact similitude as the observer beholds the terrene from the same point from which the picture was taken. In other words, the camera fixes the true perspective view of the terrene exactly as the observer's eye sees it in nature. Similarly as the observer selects certain characteristic points in nature and observes upon them, noting the result and constructing a map with the aid of the data thus obtained, he can discover and pick out the identical points on the photograph of the same terrene, and by graphical construction he will be able to draw a topographical map of the area covered by the camera's images.

The camera's image is produced by means of a biconvex lens, or rather a system of lenses, in a similar manner as we suppose a plane perspective view originates.

All visual rays emanating from an object A B to the eye *o*, form a reduced and inverted image, *a b*, on the retina. If a biconvex lens takes the place of the eye at *o*, the rays coming from A B will be refracted, and produce in the focus of *o*, a reduced inverted image *a b* of A B. Triangles *a o b* and A *o* B are similar ones. The focal distance *o m* is known or can be ascertained experimentally, for every camera, and the lengths of *a m* and *b m* are obtainable by direct measurements on the photograph. The angles *a o m* and *b o m* are also known or

given (likewise all angles which are included between the rays emanating from the point of view, and the given direction, $o\ m$, from the same point, can be measured on the photograph). The observation or determination of these (horizontal or vertical) angles becomes also necessary for the orientation of the camera-theodolite, which orientation is conditioned by the position of the optical axis of the instrument.

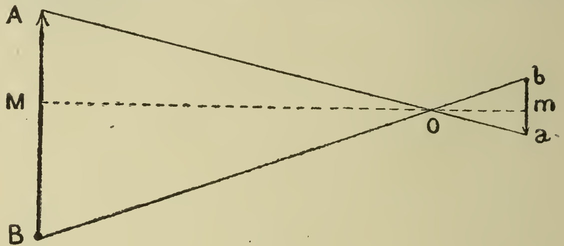


FIG. 1.

Whenever the deviation of the optical axis from a ray to any object represented in the image is given or known, the angles subtended by the optical axis and the lines to all the other points in the picture are given, both as horizontal and vertical angles, and in this fact rests the great superiority and importance of the photographic apparatus.

To transform the photographic camera into a photogrammetric camera, it was necessary to add several appliances, as the optical axis had to be made adjustable into a horizontal position for every station, the instrument had to be revolvable about a vertical axis in a horizontal plane to cover the entire horizon from one station, the optical axis was to be vertical to plane of image, etc.

The camera proper also had to receive some modifications, the chief additions being a set of cross wires. The horizontal and vertical planes became fixed on the photographs of this camera in such a manner that every picture taken with the instrument, after the same had been leveled up, showed two cross lines, which, with the optical axis (or with the vertical line to plane of image in their intersection) fixed the horizontal and vertical planes for every view. Originally this was obtained by the insertion of two very thin platina wires (crossing each other at right angles in the optical axis of camera) close to the sensitive plate, their positions becoming transmitted simultaneously with the picture to the plate by the action of the rays of light. In all instruments of more recent construction, however, the glass-plate supporter bears four small notches, which are printed upon the sensitive plate and photograph, and after the print has been dried these notch points are connected by straight lines drawn across the picture. By using sensitized films or paper instead of dry plates, a thin glass plate, inserted in the plane of image, can be provided with a system of equidistant and parallel lines (parallel to horizon and vertical plane,) which, becoming transmitted to the sensitive surface, simultaneously with the picture, will greatly facilitate measurements subsequently to be made on the photograph.

Photogrammetry or Photographic surveying.

The focal distance of this camera is made constant and it is determined for every instrument both by experiment and calculation, after having focused the apparatus with the greatest precision in regard to a sharp and well-defined reflected picture of some distant object on the ground-glass plate.

It is a well-known fact that the ordinary photographic double lens does not draw mathematically true images of the object represented, as every photograph appears more or less distorted on its edges, the minimum of distortion being in the central part of the picture. By shutting out the external rays (at a sacrifice of intensity of illumination) and by using well-curved lenses (spheroidal lenses) it has become feasible to obtain pictures which are practically correct, at least within certain limits (Mr. Meydenbaur maintains that they are true images if the angle subtended by the external rays does not exceed 110°), for all topographical purposes.

The external rays are excluded by means of a diaphragm A B inserted between the two lenses, which has a small circular perforation in its center (in the optical axis of the instrument). Annexed figure shows the combination of diaphragm and lenses.

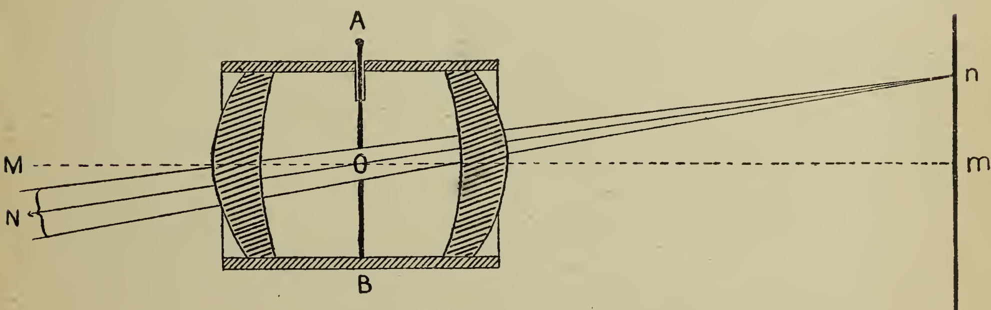


FIG. 2.

For an assumed focal distance of 200 millimetres, let the diameter of perforation at O be adopted as 10 millimetres.

Rays proceeding from a point N in nature produce the image *n* on the image plate. Owing to the perforation at O, only such rays emanating from N, which form a cone around the central ray N O *n*, with a base of 10 millimetres diameter at O, and the apex in *n* will be permitted to reach *n*.

If we designate the *principal focal distance* by f, and the focal distance of the lenses by *a* and *b* respectively, there exists the following relation between them:

$$\frac{1}{f} = \frac{1}{a} + \frac{1}{b}$$

$$b = \frac{af}{a - f}$$

Adopting for f the value of 200 millimetres, assumed above, and substituting for a different values lying between 10 and 700 millimetres, we find the following corresponding values for b:

	m.		m.
$a =$	10	$b =$	0·2041
	20		0·2036
	40		0·2010
	100		0·2004
	200		0·2002
	300		0·2001
	400		0·2001
	700		0·2000

From this tabulation we will perceive that if we have a fixed principal focal distance, say of 200 millimetres, the plane of image will intersect the cones of rays (which pierce the aperture in diaphragm) which emanate from some of the points viewed upon in a *circle* (or in an ellipse) instead of being intersected in a point (the apex of cone). This circle of diffused light increases in size with the decreasing distance of the object viewed upon (the image falling beyond the image plate) through the camera, as the instrument was focused on a distant object, and the focal distance is maintained unchanged for all operations, viewing objects near or far.

The diameter x of this circle (or ellipse) can be ascertained from the following relation:

$$x : \mathrm{O} = \mathrm{f} : a$$

$$x = \frac{\mathrm{f} \times \mathrm{O}}{a}$$

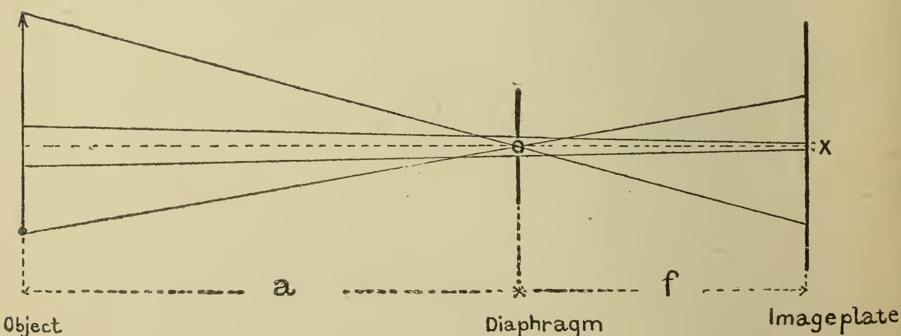


Fig. 3.

If O = diameter of aperture in diaphragm, assuming this aperture again to be 10 millimetres in diameter, and assuming the same values for f and a as shown in above table, we will find the corresponding values for x as follows:

	m.		mm.
f = 200 millimetres and $a =$	10	$x =$	0·2
	20		0·1
	40		0·05
	100		0·02
	200		0·01
	300		0·006
	400		0·005
	700		0·003

Photogrammetry or Photographic surveying.

This table shows that the diameter of the circle is very small for an aperture O of 10 millimetres, and as it has been found that a perforation of the diaphragm of only 3 to 4 millimetres in diameter gives good results for topographical purposes, the above tabulated values will become greatly reduced in practical work.

Practical tests have also established the fact that a sufficient distinctness of image is obtained at the small distance of 10 metres, as the human eye can readily locate the true center of a circle (produced by a cone of diffused light) of 0·2 millimetres in diameter, and the camera will, even at this extreme limit, give results of sufficient accuracy.

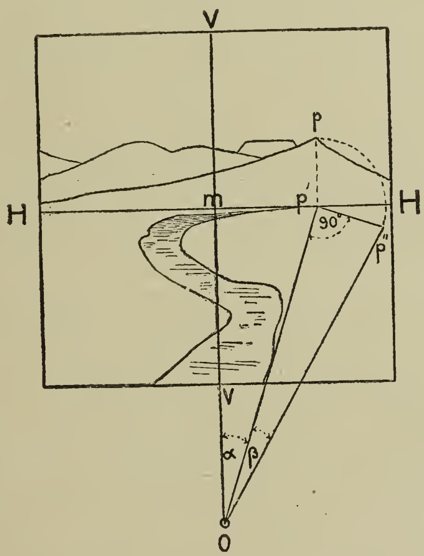


FIG. 4.

In fact, the focusing of the camera within a limit of 0·1 millimetre is extremely doubtful, being more readily obtained in the imagination of the operator than in reality. From the foregoing it will appear, however, that there can not be any objection raised against the preservation of a constant focal distance, and the operator will only have to level up the camera in the field to have it ready for work from that station.

The focal distance of a camera-theodolite is the fundamental value upon which the determinations of all angles, obtained by means of that camera, are based, and it is evident that a correct determination of this value (constant focal distance) will not only save much work, but will also avoid a number of sources of error.

Above figure (4) represents a photogrammetric picture,

H H=Horizontal thread
V V=Vertical thread

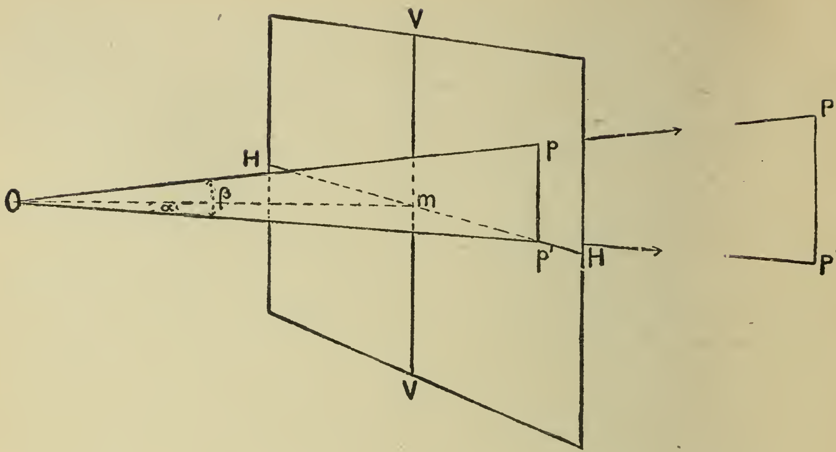


FIG. 4 *a*.

The optical axis will be perpendicular to the plane of image in the point m (Fig 4[a]). We want to find the angle α subtended by the line of vision O P (to P) and the vertical plane O V m V (Fig. 4[a]), also angle β subtended by line of vision O P and plane of horizon O H m H (elevation).

By projecting the point p upon the horizon H H in the picture, we obtain a point p'; knowing O m=constant focal distance, and m p' (found by direct measurement on the picture) we can find the azimuth α and the hypotenuse O·p' (Fig. 4) of the triangle O m p'. By measuring p p' we find the angle of elevation in the triangle O p' p.

These results are all obtained graphically, as indicated in Fig. 4, and subsequently utilized graphically in the construction of maps, employing similar methods as employed in the use of the plane table, the practical execution being far more simple than this deduction would permit it to appear.

The entire method of photogrammetry reposing on graphical measurements, the smallest length, measurable with eye and scale, will give the limit of correctness. According to Mr. Meydenbaur this limit is 0.1 millimetre.

The focal distance can be determined with great precision, even graphically, by a method which will also show the true position of the vertical thread in the picture and by repeating this operation the probable error may be reduced to 0.01 millimetre. The camera being mounted movable in horizontal plane, we can, by a series of exposures, obtain pictures covering the entire horizon. The number of exposures necessary for this performance depends upon the field commanded by the objective. Meydenbaur's instrument could sweep the horizon in six pictures, leaving a margin of 5 millimetres width common to two

Photogrammetry or Photographic surveying.

adjoining plates. All objects within such a common margin can be identified on two plates, and, by using a magnifying glass, points common to two adjoining pictures can be located and marked upon the plates which are equidistant from the vertical thread. Whenever such distances from the vertical line (representing vertical thread) do not correspond with each other, the vertical line on the picture must be shifted until they "tally." After having located corresponding points on all the pictures, covering the horizon (say, six pictures) we will have twelve determinations for the position of the vertical line. If the camera is at all fit for use, the greatest difference in these twelve positions must not exceed 0.1 millimetre. The distance between two of these *corrected* vertical lines will give the length of the picture=$2l$. For a sixfold exposure, sweeping the entire horizon, we will have the relation:

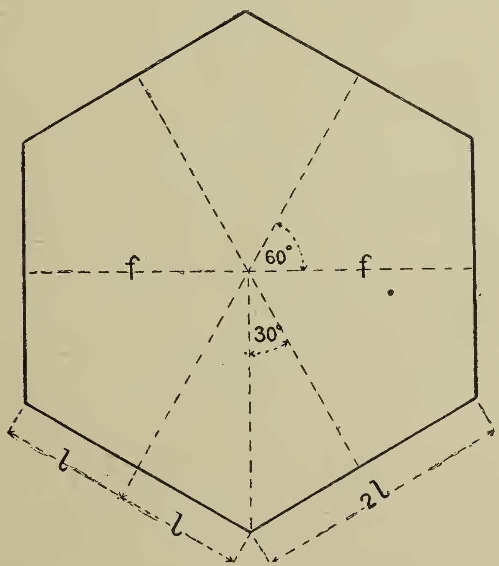


FIG. 5.

$$f = \frac{l}{tg\ 30^\circ};\ l = \text{mean value for length of picture.}$$

This is the most satisfactory determination for the focal distance of instrument, other methods being less reliable or more complicated.

When dry plates are used, it will become necessary to make an allowance for the changes which the image suffers during the process of being transferred to paper. With the exercising of care on part of the printer these changes will nearly be of a uniform character, manifesting themselves chiefly in the contraction of the paper while drying. The edges of the plate supports being printed on the edge of the picture,

and the distance of these supports being invariable on the instrument, we find in this circumstance the means for correcting the focal distance in accord with the contraction of the paper.

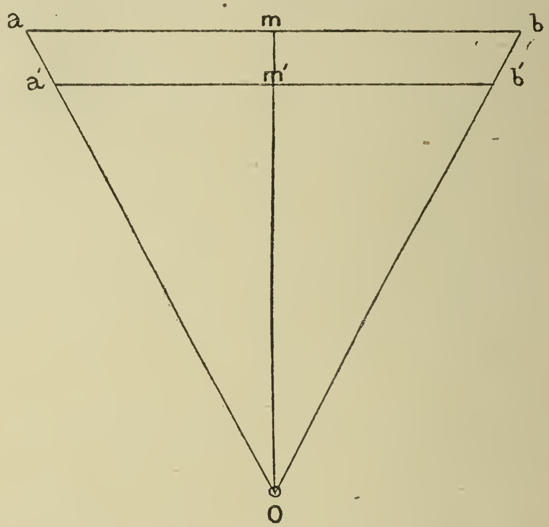


FIG. 6.—$a\ b$=original length of picture between plate supports in camera. $a'\ b'$=length of picture after having been transferred to paper and dried. m O=focal distance of camera.

By laying down the triangle $a\ b$ O and placing the length of printed paper $a'\ b'$ parallel to $a\ b$, and moving it from $a\ b$ until a' falls upon a O and b' upon b O ($a'\ b'$ being still / to $a\ b$), we find point m', and can measure length of O m'= focal distance for contracted picture.

In order to distribute the weight of the camera-theodolite as nearly as possible upon the three leveling screws of the instrument, and thus facilitate its setting up and hauling, the optical center necessarily falls outside of the vertical axis of the camera. During a circular movement of the camera plate (surveying the horizon) the optical center will describe a circle of about 0·20 centimetres in diameter for ordinary instruments. In other words, the station point and optical center of pictures will not coincide with each other. The optical centers of the six pictures covering the horizon are, in reality, situated on the circumference of a circle of 0·2 centimetres diameter in the form of a regular hexagon.

For a scale of 1–1000 for the survey, the diameter of this circle will be only 0·0002 metres long, about the size of a fine needle puncture. For all topographical purposes, therefore, we can assume the optical centers to fall into one point—the station point.

The maps are constructed from photogrammetric pictures in the same manner as the plane table is used, and the operations may be described as follows:

Photogrammetry or Pphotographic surveying.

ORIENTATION OF THE PICTURES.

The simplest case would be that a base line had been measured, and pictures of the terrene had been taken from both end stations of this line. While occupying one end of the line, the other must be marked by some plain signal, which will be readily seen on a picture. In the pictures taken from the Stations (I and II) this signal should appear on plate I as a heavy short line, showing two flags (Fig. 7). The horizontal

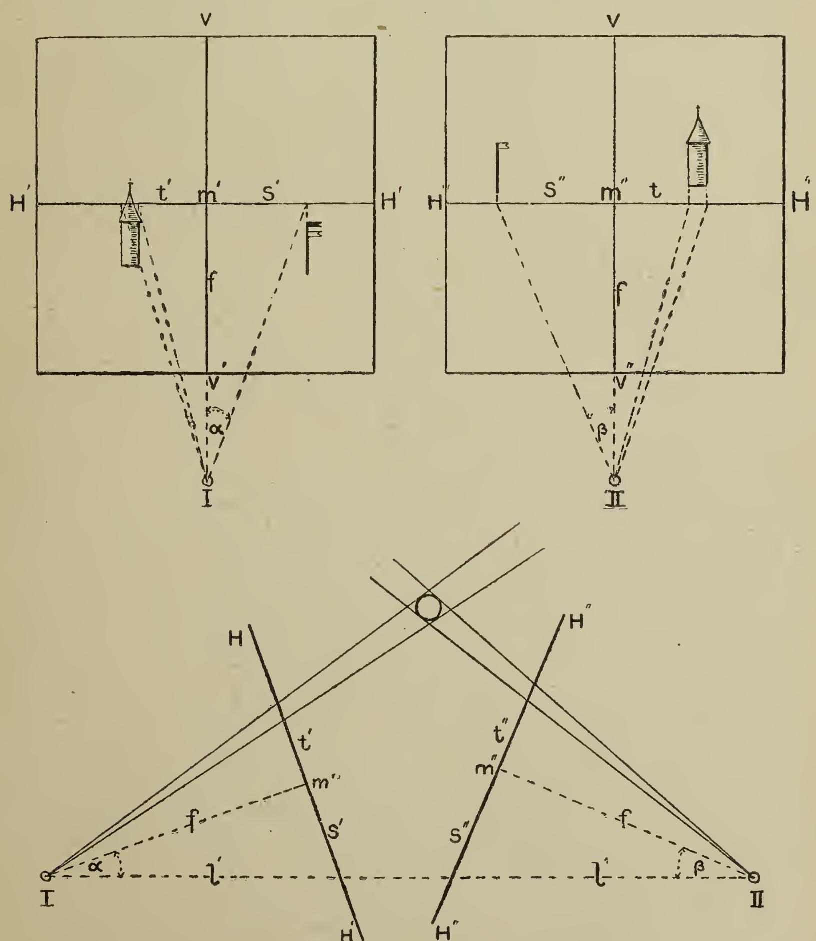


Fig. 7.

angle subtended by optical axis of instrument and the base line, during each exposure for the pictures, can readily be obtained graphically, as indicated in figure and described in preceding chapters. The size of these angles is entirely arbitrary and it is only necessary that the signal may appear at least on one of the pictures, even if the entire horizon is not covered by the exposures.

After having plotted the base line I–II (preceding figure) in reduced scale, the angles α and β are plotted with reference to the pictures to which they belong, and on these directions of the optical axis the known focal distance f is laid off from points I and II and the vertical lines (horizons $H' H'$ and $H'' H''$) drawn through their ends. All the other pictures (having no special signal for orientation) are oriented as soon as the first one of the six has been oriented, as above, owing to the division of the horizon into six pictures, and herein rests the main advantage of the hexagonal division.

The entire orientation of the pictures is accomplished in a very short time, inasmuch as the triangles are all rectangular ones with known sides (f, *t* and *s*). The known focal distance f is laid off from *m* downward along v *m* v in the pictures, and after projecting the points of images upon the horizon we find *s* and *t*.

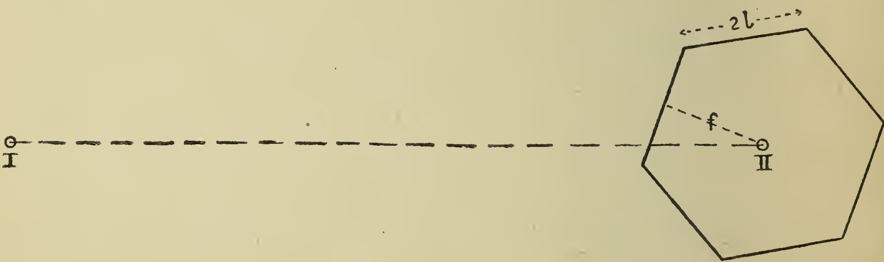


FIG. 8.

After the horizons have been located as shown above, the horizontal projection of any point, common to two plates, is found by intersecting. Thus the circular tower, indicated on the pictures taken from the Stations I and II is located. The distances *t* of the two sides of the tower from the vertical thread are plotted from *m′* and *m″* upon the horizons H′ and H″ respectively, new lines (rayons) are drawn from the end stations of base line I–II through these points, which lines intersect each other in a quadrangle, the inscribed circle of which locates the horizontal projection of the tower. The photogrammetric plotting is altogether very much like the plotting on the plane table, and, generally speaking, photogrammetry has the same advantages and disadvantages adherent to the plane table, except that the duration of the field work is reduced to a minimum.

In case the base line, or the line from which the observations are made, is not situated in the area to be surveyed, the orientation of the pictures can only be made with reference to a point or signal not situated on the base line, the position of which, in reference to the base line, however, must be known or determined. For this and similar purposes, Mr. Meydenbaur's instrument is convertible into a plane table by removing the camera and clamping a sheet of paper upon the camera supporter table, after which, lines of direction to the distant "object of

Photogrammetry or Photographic surveying.

orientation" can be taken from both ends of the base line with the aid of a small alidade. By combining a compass with the camera additional advantages may be obtained.

After the horizontal projection p' of any point p has been constructed, the relative height P P′ of this object above the horizon of the instrument or picture can be readily found, as follows (Figs. 4 and 4[a]):

O p and O p' found from horizontal projections, $p\,p'$ measured directly on surface of pictures.

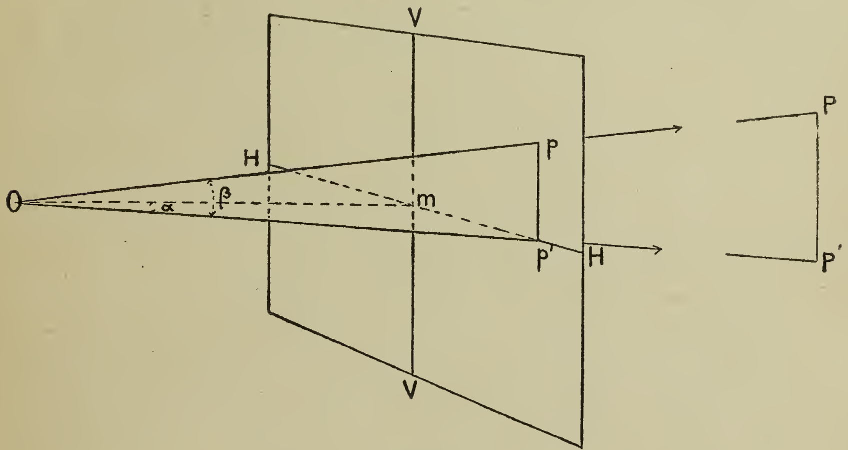


FIG. 4*a*.

We have the relation:

$$\mathrm{P\,P'} : p\,p' = \mathrm{O\,P'} : \mathrm{O}\,p'$$

$$\mathrm{PP'} = \frac{\mathrm{O\,P'}\;p\,p'}{\mathrm{O}\,p'}$$ (with reference to the scale of the map).

Measurements on the pictures are preferably made with a small ivory scale divided into millimetres. After some practice, the eye can estimate 0·1 millimetre very closely.

If a difficulty appears in finding or locating identical points on pairs of pictures, photogrammetry can not be employed. Still, with the erection of a few signals this evil may be remedied also. Owing to the fact that every point must be shown at least on two pictures in order to locate the same on the horizontal projection, an error of identity of a point in question is very improbable, insomuch as the twofold determination of the elevation of any doubtful point will give a good check; both elevations determined from two plates must give the same result if the point has not been mistaken for another.

After a sufficient number of elevations have been plotted upon the map it will be an easy matter to draw the contours by interpolation, which operation will be greatly facilitated by studying the pictures

taken of the terrene, from their different stations, just as one might take a map out into the field to sketch in some doubtful detail.

The scope and productiveness of the photogrammetric method greatly exceed the bounds which formerly surrounded the field operations of lower geodesy, as the following remarks may show:

A scientific exploring party may have sent home a number of photogrammetric pictures of their route of travel with the necessary data for orienting the pictures, and also sent the elevations of their horizons, H H, determined by aneroid barometers in this case. A distant mountain range may appear on two or more views, visible only in outline, owing to the great distance. It is possible to construct a system of contours which will represent the range with a considerable degree of accuracy.

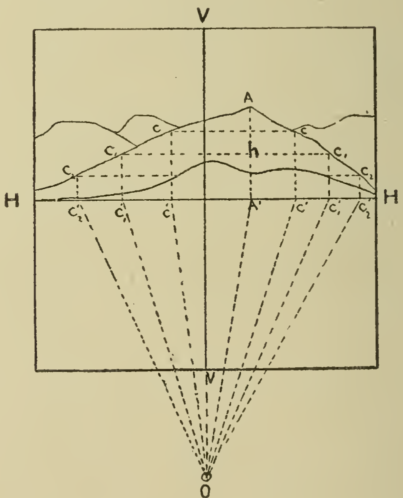


FIG. 9.

For this purpose we locate the horizontal projection A′ of the summit A, if it can be readily identified on several pictures, then ascertain the elevation *h* of A above horizon H H, which height we divide into a number of horizontal strata (with reference to the elevation of A above H H in the different pictures) in such a manner that the corresponding dividing planes are on the same level. Above figure represents one of the pictures thus divided into strata, the lines O C, O C_2 represent the tangential lines drawn from focal center O to the contours, as indicated by the dividing of planes of strata. These tangents are, it is true, not in the same plane as their corresponding dividing planes, but owing to the great distance of A from O this will cause an error too small to affect the map.

Adjoining figure represents the result of this operation after having drawn tangential lines from three stations, I, II, III (from the latter only the tangents to lower contour line drawn), and it is evident that

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this method surpasses any other which an exploring expedition may have at command to determine the scope and elevation of terrene lying at a distance. The circumstance that the result obtained can be worked out at home, without the presence of any member of the scientific corps of explorers being necessary, seems to be another point in favor of the photogrammetric method. Military reconnaissance in times of war

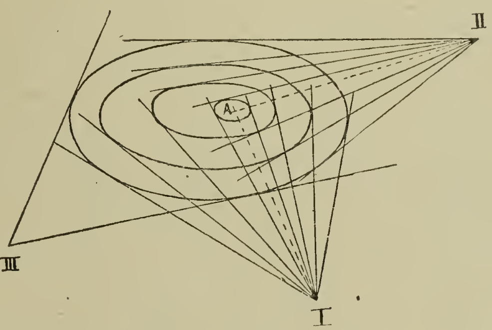

FIG. 10.

(secret surveys), preliminary surveys for engineering purposes in uninhabited, mountainous countries, etc., will find great help in photogrammetry, particularly when combined with the plane table, alidade, and barometer.

REPORT OF COMMITTEE ON METHODS OF BALLOON SURVEYING.

[Presented by Assistant D. B. Wainwright.]

Your committee begs leave to submit the following report on that portion of Assistant Bache's paper relating to topographical surveying by photography from a captive balloon, which was read to the Conference at its second session.

Your committee believes, from a short study of the subject, that it is perfectly practicable to have a balloon made as described by Assistant Bache, and to suspend frem it a camera in the manner he represents, which will be sufficiently free from oscillation to obtain an accurate picture of the field of view.

Also, it seems to us feasible to hold the balloon in position,* or nearly so, over a given point by a set of four guys; and it is undoubtedly practicable to control the moment of exposure by an electrical device such as he indicates, connected with the shutter of the camera. Moreover, a traverse line laid out on level ground and marked in the manner given by Assistant Bache would serve as a means to correct any

* The height suggested by Assistant Bache is from 250 to 300 feet.

distortion of films or prints due to chemical processes, and any distortion due to perspective of lines lying in the same horizontal plane as the traverse line. But it is our opinion that the plan proposed is open to two serious objections which militate against its practical use—

(1) The amount of time comsumed in mapping by this means a given area, owing to the small surface obtained by one operation or picture; the difficulty in moving forward the guys through bushes and trees or past buildings, and in preparing a new traverse line.

(2) All objects not lying in the same horizontal plane as the traverse line would appear on the picture out of place according to scale; thus an object on a hill 50 feet high and distant horizontally 150 feet from a point directly under the camera would measure, according to scale, over 175 feet from the same point;* and so for all objects above or below the plane of the traverse line a special reduction of each, according to height, would have to be made, necessarily involving a large amount of work and proving a fertile source of error.

It is not to be inferred from the criticism of the present plan that your committee holds an unfavorable opinion of all photography as applied to surveying. It believes a reasonably accurate map, of small scale, could be made of a flat or gently rolling country from a balloon at the height of several thousand feet, if only a balloon were susceptible of management at that height. It also believes that the question of mapping mountainous regions by means of cameras directed horizontally is worthy of discussion and investigation.

In conclusion, this committee would state that there appear to be serious doubts as to the applicability of the proposed method to the conditions practically existing in Coast Survey work; and though not feeling warranted in recommending any outlay in making the experiment, it acknowledges that if a sufficiently large area to afford a thorough test were surveyed, data would be furnished of much interest and probable value for a comparison in rapidity, accuracy, and expense between this method and those ordinarily used.

Supplement J.

CONVENTIONAL SIGNS FOR FIELD SHEETS.

See page 576 for an abstract of the report of the committee appointed to secure still greater uniformity than heretofore in the use of conventional signs on the original charts of the Survey.

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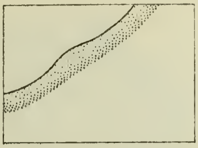
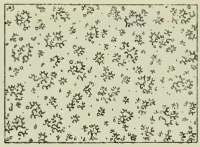
* Balloon supposed to be 300 feet high.

Shoreline Low Water

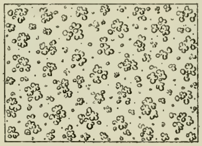


Oak

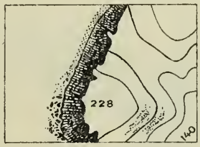


Rocky Ledges

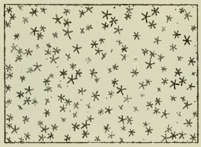
Deciduous and Undergrowth



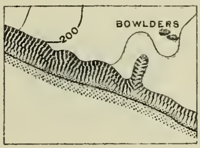
Rocky Bluff



Pine



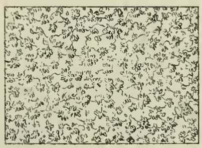
Eroded Bank



Palmetto

Sand and Shingle

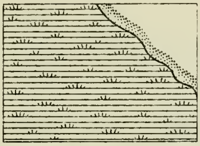
Mangroves



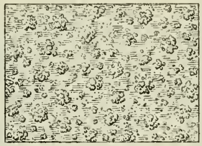
Sand Dunes

Cacti

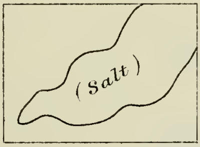
Salt Marsh



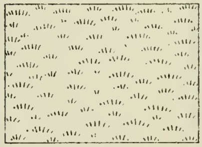
Cypress Swamp



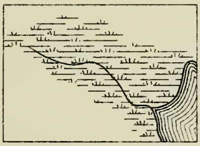
Salt Pond



Grass



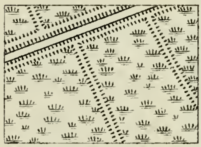
Fresh Marsh and Fresh Pond



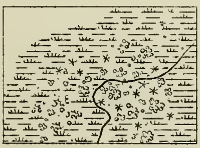
Orchard

Oyster Bed

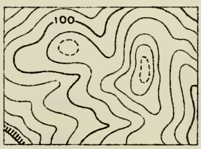
Rice Dikes & Ditches



Wooded Marsh

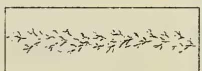


Curves of equal elevation and intermediate curves

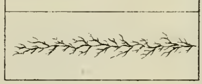


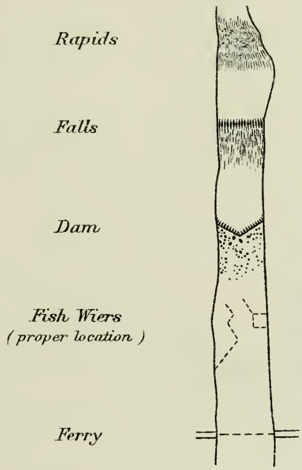
Submerged Marsh

Eel Grass



Kelp





Topographical Station ⊙

Triangulation Point △

Dwelling House

Barn

Shed and Pen

Ruins

Windmill

Church

Cemetery

Fence

Public Road

Road fenced on one side

Telegraph Road

Railroad (each track)	
Railroad (large Scale)	
Road not fenced	
Path or Trail	
Stone Wall	
Hedge	
Embankment	
Canal and Lock	
Known Altitude	420 ft.
Approx "	(approx) 420 ft.
Lighthouse (rays red)	
Light-ship (" ")	
Buoys (Can, Nun, Spar and Bell)	
Red and Green	
Black	
Horizontal Stripes	
Perpendicular Stripes	
Whistling	
Lighted	
Mooring	
Beacon (Lighted, rays red)	
Spindle or Stake	
Anchorage	
Wreck	
Rock awash	
Sunken Rock	+

SUPPLEMENT K.

LETTER FROM MR. HENRY GANNETT, CHIEF TOPOGRAPHER OF THE U. S. GEOLOGICAL SURVEY, DESCRIBING THE METHODS EMPLOYED ON THAT WORK.

DEPARTMENT OF THE INTERIOR,
U. S. GEOLOGICAL SURVEY, GEOGRAPHIC BRANCH,
Washington, D. C., February 19, 1892.

MY DEAR SIR: At a meeting of officers of the Coast and Geodetic Survey last Tuesday, to which myself with others connected with the U. S. Geological Survey were invited, a question was asked by Mr. Ogden the substance of which, as I recollect it, was as follows: "Can you, as a result of your experience in topographic surveying, suggest any improvements on the methods the Coast and Geodetic Survey is now pursuing whereby its work may be more rapidly or economically carried on?"

At the moment I did not feel prepared to answer this question, but, upon consideration, it appears to me that a condensed statement of the organization and methods in use upon the Geological Survey may serve to develop the points of difference between the practice of the two organizations, from which the officers of the Coast and Geodetic Survey may select such features as, from their experience, seem desirable and fitted to the conditions under which their work is prosecuted.

Primarily, it is understood throughout the Geological Survey that the work is carried on for the sole purpose of making maps upon certain predetermined scales, and all the operations of the Survey are subordinated to this end. The primary triangulation is carried on merely for the purpose of controlling these maps, and the maximum allowable error in the work is limited only to that permissible upon the maps. Such being the case, the primary triangulation is comparatively cheap, from ten to twenty stations being occupied per month. A single occupation of a triangulation station is generally sufficient, and twelve to sixteen pointings upon each other station are made. Artificial signals are used throughout in the work. Such rapid progress is not, however, inconsistent with considerable accuracy in the results. For example, the triangulation in Kansas, executed in 1890, with an 8-inch theolodite reading by micrometer to two seconds, showed an average error of closure of 1–95, in one hundred and twenty triangles.

By the primary triangulation, three points are located immediately on or adjacent to each atlas sheet, such sheet comprising upon the scale 1–62500, 250 square miles, and upon the scale of 1–125000, 1 000 square miles. These sheets are projected, the primary points are plotted upon them, and all work from that point on is relegated to the

plane table. With this instrument all points capable of being located by triangulation are so located. For this purpose, a score or more of points are occupied upon each plane-table sheet, their positions having been determined prior to occupation whenever possible. Signals are used upon all points to be occupied. Points located, but not occupied, are not, as a rule, marked by signals. Such points consist of hilltops and other relief features, houses, churches, and other features of culture, points in the shore line, and any other points in the hydrography of the region which are susceptible of being so located. In other words, location by triangulation is carried on as far as is economic. This method of location serves two purposes. First, to aid in the location of the sketching, and, secondly, to locate in correct position the traverse lines. All this work is done by the Johnson plane table and with a telescopic alidade of considerable power.

Traversing, by which location is effected by direction and distance measurement, is carried on to a large extent. All roads are traversed, since it is the cheapest method of obtaining their alignment, and in unsettled parts of the country it is found necessary to run many traverses where no roads exist in order to supply the requisite control for the sketching. In the eastern parts of the country, roads average from 1 to 2 linear miles to every square mile of country, involving an enormous amount of traversing merely to obtain the roads. This traversing of roads serves also for the location of countless points in addition to those located by triangulation, forming a network closely covering the country. Traversing is done with the simplest possible plane table, which is oriented by compass. Directions are measured with a ruler having raised sights. Distances are measured by counting the revolutions of a wheel directly or by some form of odometer. Large numbers of minor points are cut in from the traverse lines. The traverses are fitted to the triangulation executed with the larger plane tables.

Datum points for heights are obtained by the use of the wye level. Secondary heights are measured by the vertical arc of the alidade, and elevations along traverses are in the main measured by aneroid closely checked by instrumental determinations, and to some extent by instrumental profiles.

The Geological Survey makes a clear distinction between instrumental determinations of position, which is characterized as the control of a map, and the sketching, which is recognized as artistic work. The sketching is done upon a skeleton map, which contains all the control, and it is done by the best sketchers available. The selection of stations for sketching is done with considerable care, regard being had to obtaining the best positions for seeing the country in its proper relations. Upon the scale 1–62500 sketching is rarely attempted at a distance greater than a mile and then only when it seems impracticable to obtain nearer views; as a rule, the sketching is done at much

shorter distances. The matter of generalization has received much attention, the fact being fully recognized that all maps must be in a greater or less degree generalized from nature. In connection with this as an immediate adjunct, the study of structural geology in its influence upon topographic forms has become a part of the education of the topographer.

The organization of the parties is simplified as far as is consistent with efficiency. A party engaged in primary triangulation consists ordinarily of the head of the party, a helper, and a man to build signals. A party engaged in plane-table triangulation consists of the plane-tabler and a helper. A horse and buggy is provided for carrying them about. A traverse party consists of a traverse man, with the necessary horse and vehicle, and the traversing is generally done by low-salaried men, since it does not require a high degree of skill. No rules regarding office hours obtain in the field, but men are expected to work all day.

The list of features represented upon the maps embraces all natural features of magnitude sufficient to be represented upon the scale, and all artificial features which are of public, as distinguished from private importance. Thus, there are represented boundaries of civil divisions, cities, townships, counties and States; houses, railroads, roads, streets, canals, bridges, fords, light-houses, etc. The outlines of wooded areas are mapped. There are not mapped fences, cultivated lands, or any other features which relate to the individual, rather than to the community.

The plane table triangulation of an atlas sheet, including some 250 square miles, occupies from one to two weeks in putting up signals and measuring angles, according to the extent to which this work can be carried. The traversing of such an area ordinarily requires about fifty days' work of one man, since a man traverses, on an average, about 10 linear miles per working day. The sketching of such an area requires from one to two months, according to the intricacy of the work, and the readiness and the facility of the sketcher. On an average, a party, consisting of its head, who does the triangulation and sketching, and one traverse man, with a helper, will survey entirely two atlas sheets per season.

As a matter of interest, I append to this a table showing for the Northeastern Division of Topography the area surveyed during the last season, the number of points located by plane-table triangulation, the number of miles that were traversed, and other derived data.

STATISTICS OF CONTROL, NORTHEASTERN DIVISION, U. S. GEOLOGICAL SURVEY.

[Scale 1-62500; contour interval, 20 feet.]

Area surveyed (square miles)	3 150
Triangulation stations	650
Number of square inches per station	47
Points located by triangulation	3 330
Total triangulation stations and located points	3 980
Number of above locations per square inch	1·3
Number miles traversed	4 460
Inches traversed per square inch	1·4
Number traverse stations	29 150
Traverse stations per square inch	9·3
Total locations per square inch	10·6
Traverse stations per linear mile	6·5
Heights measured with vertical circle	5 700
Heights measured by aneroid	23 886
Total measured heights	29 586
Heights per square inch	9.4

These locations are regarded as sensibly accurate upon paper, as indeed they must be, as otherwise the work would come to a standstill. The imperfections of the maps are to be looked for in the sketching, where they may be due to insufficient control, to inexpressiveness of the sketching, or to both causes combined.

I inclose with this a tracing, showing the amount and the distribution of the control upon a sheet surveyed in West Virginia during the past season, which will further illustrate this matter. (See illustration No. 31.)

Thanking you and the other gentlemen composing your commission for your courtesy in inviting us to join you in your deliberations, I remain,

Sincerely, yours,

HENRY GANNETT.

Chief Topographer, U. S. Geological Survey.

Prof. HENRY L. WHITING,

U. S. Coast and Geodetic Survey, Washington, D. C.

COMMENTS BY ASSISTANT H. G. OGDEN ON THE PRECEDING LETTER.

[Submitted February 24, 1892.]

The letter from Mr. Gannett, Chief Topographer of the U. S. Geological Survey, to the Chairman of this Conference, offers us an opportunity of comparing the methods employed by the U. S. Geological Survey in making topographic surveys with those employed by the Coast and Geodetic Survey.

Before instituting this comparison, however, I desire to say a word on the question I propounded to our associates of the Geological Survey

WEST VIRGINIA BUCKHANNON SHEET No. 31

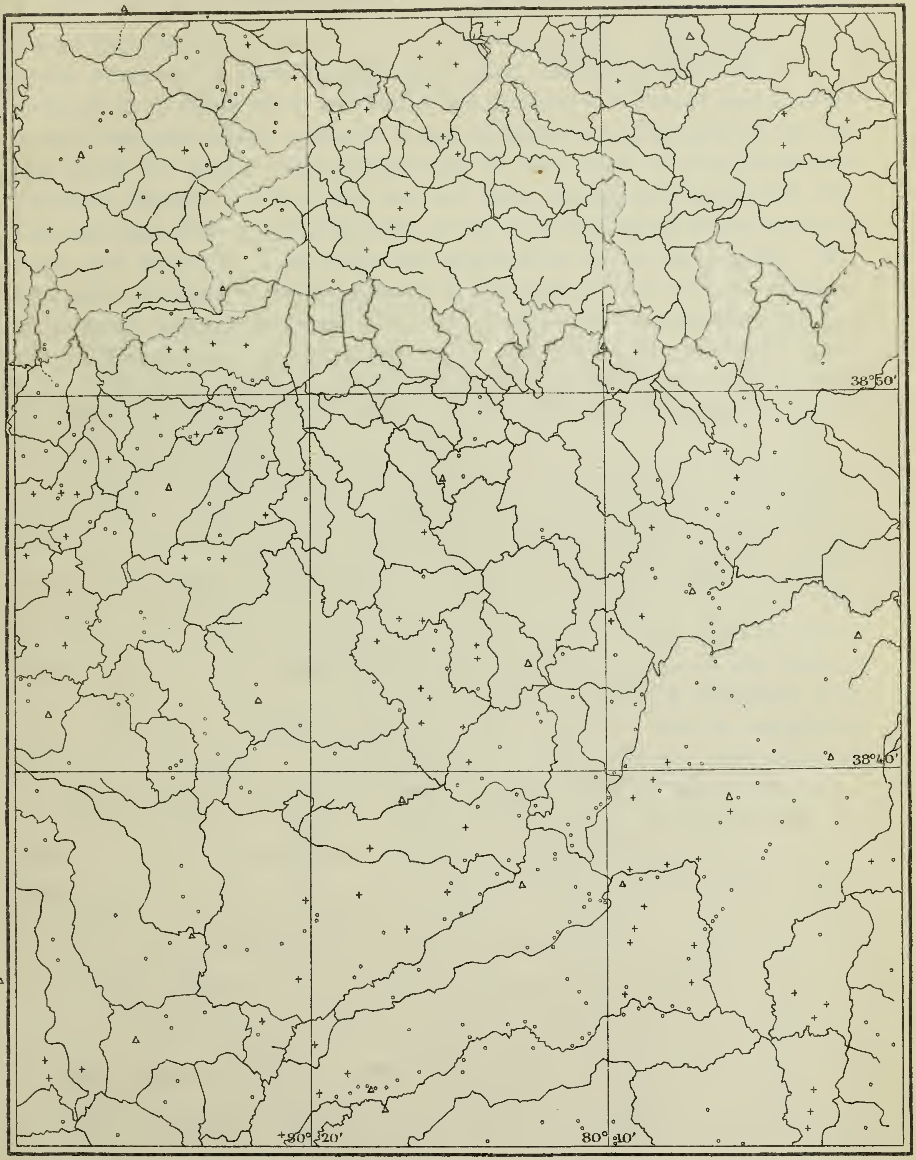


Diagram showing distribution of control work

Statute Miles

5 0 5 10

Main and Secondary stations .... △
Intersections from stations .... ∘
Intersections from traverse .... +
Traversed Roads or Trails .... ∼

Comparison of methods of making topographical surveys in the U. S. Geological Survey and in the U. S. Coast and Geodetic Survey.

when they joined us in conference a few days since. The subject I had in my mind at the time was similar to that stated by Mr. Gannett, but differed in so much that, I asked if the gentlemen present would state to us what part of the methods in use by them in topographical surveying could be applied advantageously to the work of the Coast and Geodetic Survey. While this has not been specifically answered, Mr. Gannett has, with great kindness, given us a statement of the methods used, and leaves to us to make the application to our own work. Mr. Gannett's statement refers entirely to the eastern half of the continent; it does not include the regions of the West, which, topographically, are very different, and are surveyed by a different method. As I have been informed by Mr. A. H. Thompson, the plane table alone is used in California, even in running such traverse lines as are found necessary through wooded areas.

The method described in Mr. Gannett's letter involves several operations, and covers the ground several times before the survey is plotted. It will be observed that a triangulation with computed sides is first spread over the area, furnishing a sufficient number of points to permit the use of the plane table in interpolating intermediate stations. The ground is then covered by a plane table triangulation in which elevations, so far as practicable, are determined by means of the vertical arc. Up to this point we may say that the method is identical with that employed on the Coast and Geodetic Survey. But in supplying the details of shore line, roads, elevations, etc., that are still required to complete the survey, the methods employed are radically different.

On the Geological Survey, the system of traverse lines forms the basis for the determination of all these details, these traverse lines being tied on to the stations of the triangulation and the plane table. Sometimes, in running the traverse lines, elevations are also determined, either by angulation or by the barometer, but I judge from the description given us that in many instances, after the traverse lines have been obtained, the ground is again covered with the barometer survey. But whichever way this traverse work may have been conducted, it seems plain that after it has all been completed and adjusted into place, the elevations being given also, the sheets, or sections of sheets, are taken in the field by still another party or officer of the party, and the hill work sketched in by the data on the sheet of traverses; this officer checking the previous work, as may be required, by the barometer, and running such additional traverse lines as he may find necessary, where the work furnished him has not cut up the country sufficiently close to permit the sketching of the contours within the limits of error that may be prescribed.

The same details are obtained in the Coast and Geodetic Survey with the plane table, the elevations being determined with the vertical

are, and the shore lines and roads being located directly by plane table stations over the whole area, only such traverse lines being run, and these almost invariably with the plane table, when a strip of country is encountered in which plane table stations can not be made, for instance, a dense wood in such a level region that it is impossible to see out to the determined points.

This statement shows that in the method employed by the Geological Survey the ground has to be covered at least four times, and it may happen five times, whereas, in the method of the Coast Survey, it is covered but twice. It seems to me that this, in itself, is such a saving of time that there can be no question as to the preference of the Coast Survey method in conducting work such as is required in the Coast and Geodetic Survey; that is, a large scale, with intricate shore lines and details of high cultivation, to be represented on the map. But the method of the Geological Survey is still further objectionable, if we should attempt to apply it to our own work; for the labor of plotting the traverse lines and details involves in work of such intricacy as ours an amount of time that is almost equal to the time consumed in making the survey in the field. It may be observed, also, that the method of the Geological Survey would be most laborious and almost impracticable in determining many of the shore lines on the New England coast with the degree of accuracy that is required. There can be no doubt that this feature in surveying is more rapidly and economically traced by the plane table, and that in many instances it is the only instrument with which a control of the shore can be satisfactorily obtained.

In discussing these methods I am led to the opinion that to adopt the methods of the Geological Survey, as they have been given to us by Mr. Gannett, as a substitute for our own in the prosecution of topographical surveys for the Coast Survey, would lead to an increase in the cost of the topography per square mile so large that it would practically be prohibitive.

While considering this question of methods I ask your indulgence for a few moments longer to express my views on section 4 of the Superintendent's opening address to the conference.

We have already expressed ourselves most forcibly that in our own topographical work we can see no very material modification that can properly be made, either in the detail that is given or in the method that we employ; that we believe experience has fully demonstrated the economy of our methods, and that they are superior in accuracy and rapidity for the same class of work over any methods employed by any topographers the world over, so far as we have been able to ascertain.

The second part of this section of the Superintendent's address refers to methods for making topographic surveys of less refinement, and to be at a reduced cost. The subcommittee to which was referred the cost

Comparison of methods of making topographical surveys in the U. S. Geological Survey and in the U. S. Coast and Geodetic Survey.

of work has referred to this question at considerable detail in their report, but did not enter into the details of actual methods.

In any region where it is practicable to use the plane table alone it is, in my opinion, the cheapest and most rapid method that has yet been devised, either for an accurate survey or for a survey of less precision, with greater generalization. The cost per square mile, wherever a survey is made with this instrument alone, must depend very largely upon the details that will be shown upon the map, aside from the personal equation or the expertness of the officer manipulating the instrument. There are, however, many regions so densely wooded, and at the same time broken with deep ravines, that it is essential to use some auxiliary instrument to locate details. The methods employed for this purpose on the Geological Survey are at once suggested as those most available in a country of this character; but it should be observed that to use these methods, so far as they relate to detail only, would not produce a satisfactory result, as the work would be very imperfectly oriented in its different parts, rendering directions and distances very uncertain. The Geological Survey has recognized the failure of these methods when used alone, and has strengthened them in the only practicable way by covering the ground with a triangulation of reasonable strength and interpolating other points with the plane table.

The scale on which the survey is made necessarily affects the cost of the work in a general way. If the scale is large, it requires more stations to represent the features that can be shown upon the map. If the scale is small, these features are generalized, to a certain extent, and the number of stations that would be required is less. The advantage, therefore, of the small scale in reducing the cost should at once become apparent. On the other hand, the scale of the work should be sufficiently large to represent a reasonable detail of the features of a country. In the work of the Conference we have given expression to the opinion that a survey should not be made upon a scale smaller than 1–40000; that the generalization required on a smaller scale is too great to preserve the degree of accuracy that should be attained to make the survey useful for the general purposes that a topographical survey may subserve.

To describe in detail the different methods that can be used in covering the country rapidly, but still with sufficient fullness to render all the salient features recognizable, would involve a labor too great to be undertaken by this Conference or any individual upon it. There are new instruments that could be made very useful in such a work; that would modify to some extent methods that have heretofore been used by topographers. But unless there is a specific statement as to the degree of accuracy that shall be required, and the detail that shall be represented, I believe to draw up any plan for such surveying would be labor thrown away.

In conclusion, I have only to say that the expert topographer, with experience behind him in making topographical surveys of precision, is in general well equipped to undertake rapid and inferior work when required. But I do not wish it to be inferred from this statement that the expert topographer is necessarily expert in the execution of inferior work, for, besides the ability to manipulate instruments and to grasp the features of a country, a long experience is required to enable him to present them on a map in the most intelligible form; and therefore, when we wish to reduce the cost of work, I believe it is essential we should consider the experience of the men who may be detailed to execute the work in the field.

My personal experience on the Coast Survey satisfies me that to produce the most economical results we require a school of topography. Young men who may be selected to learn this class of work should be given ample opportunities in different parties on different sections of the coast to learn the individual methods of the more experienced men, before they are permitted to undertake any work by themselves.

SUPPLEMENT L.

FORMULA FOR COMPUTING DIFFERENCES OF ELEVATION—A SIMPLE AND PRACTICAL FORMULA FOR THE COMPUTATION, WITHOUT THE USE OF TABLES, OF DIFFERENCES OF ELEVATION CORRESPONDING TO GIVEN DISTANCES AND SMALL VERTICAL ANGLES, WHEN THE SAME UNIT OF LENGTH IS EMPLOYED FOR DISTANCES AND HEIGHTS.

[By W. C. Hodgkins.]

As is well known, the empirical formula for the computation of heights, given in the Coast and Geodetic Survey treatise on the plane table is based upon the use of the metre as the unit of distance, and of the foot as the unit of height. It is therefore not applicable to the case under consideration.

For ordinary purposes the formula for the difference of height may be stated with sufficient accuracy thus:

$$h = \pm \mathrm{D.}\ \tan \alpha + c \left(\frac{\mathrm{D}}{1000}\right)^2$$

where h represents the difference of the height, D the distance, α the vertical angle and c a constant coefficient of curvature and refraction. If now we call the number of minutes in the angle a and using the metric system take K for the distance in kilometres we have

$$h = \pm \mathrm{D}\ a \tan 1' + c.\ \mathrm{K}^2$$

Formula for computing differences of elevation.

The tangent of 1′ is 0·0002909 or $\frac{0{\cdot}2909}{1000}$; therefore

$$h = \pm\, 0{\cdot}291\ \mathrm{K}\ a + c\,\mathrm{K}^2$$
$$\therefore\ h = \pm\, 0{\cdot}291\ \mathrm{K}\ a + 0{\cdot}07\ \mathrm{K}^2$$

c may be taken as $=0{\cdot}07$. Also, 0·291 very nearly equal $\frac{7}{24}$ or $\frac{1}{3}-\frac{1}{24}$ that is, $\frac{1}{3}-\frac{1}{8}$ of $\frac{1}{3}$.

For the first term, therefore, we have the following rule:

Multiply the distance in kilometres by the angle in minutes, divide the product by three, and subtract one-eighth of itself.

The same result would be obtained by taking one-fourth of the product and then *adding* to the quotient one-sixth of itself.

For the second term multiply the square of the distance in kilometres by 0·07.

For angles from zero to 4° the decimal coefficient is more precise than the common fraction, but the latter gives sufficiently close results at all ordinary distances, with angles not greater than 6°.

With larger angles it should be used with caution, and only for short distances, though under such circumstances the errors arising from its use are smaller than if the decimal coefficient were used and are less than half as great as those occurring in similar use of the old formula of the "Treatise." As this coefficient $\frac{7}{24}$ is larger than the decimal coefficient 0·291 by about $\frac{1}{417}$ part of the latter, it gives for small angles results which are larger than the true differences; and as up to about 3° the tangents of angles are sensibly proportional to the angles, this error is greatest with vertical angles of about 3°, when it amounts to 13 centimetres per kilometre.

As the tangents of the angles above 3° increase more rapidly than the angles, the error arising from the use of the coefficient $\frac{7}{24}$ decreases as the angle increases, up to 5° 7′ when the formula is exact (for all ordinary purposes). For still larger angles, the tangents rapidly increase and the formula gives results which are too small by a constantly increasing difference.

Thus at 6° this error is 10 centimetres per kilometre; at 8° it is 54 centimetres, and at 10° 109 per kilometre. With this last angle (10°) the decimal coefficient gives an error of $1{\cdot}73^{\mathrm{m}}$ and the formula of the "Treatise" an error of $2{\cdot}88^{\mathrm{m}}$ per kilometre.

Obviously this formula applies equally well with any unit of length, except that instead of K we should use $\frac{\mathrm{D}}{1000}$; and to exhibit the details of the operation we may write the formula thus:

$$h = \pm \frac{1}{3}\,\frac{\mathrm{D}a}{1000}\left(1-\frac{1}{8}\right) + 0{\cdot}07\left(\frac{\mathrm{D}}{1000}\right)^2$$

SUPPLEMENT M.

A TREATISE ON THE WAGNER TACHYMETER AND TACHYGRAPHOMETER AS MADE AT THE MATHEMATICAL INSTRUMENT WORKS OF OTTO FENNEL AT CASSEL, PRUSSIA, WITH AN INTRODUCTORY ESSAY BY J. L. LIČKA.

[Translated from the German by W. C. Hodgkins, C. E., Assistant, U. S. Coast and Geodetic Survey.]

TRANSLATOR'S PREFACE.

The following pages are translated from a pamphlet published by the makers of these instruments under the title, "Die Wagner-Fennel'schen Tachymeter des mathematisch-mechanischen Instituts von Otto Fennel in Cassel. Cassel 1886," a copy of which was kindly loaned me by Assistant Edwin Smith, chief of the Instrument Division of the Office of the Coast and Geodetic Survey.

The translation was originally made during the sessions of the Topographical Conference for my own information in regard to these instruments, the special feature of which, the Wagner "projection apparatus," was new to me, as I think it must be to many engineers in this country.

During the last days of the Conference its members had the opportunity to examine personally a theodolite tachymeter of the above make. I was much interested in the instrument, which appeared very well made, but seemed to me unnecessarily heavy and cumbrous. Such a matter of detail might, however, be easily remedied, and while I was forced to agree with the opinion of the other members of the Conference that in its present form it is not adapted to the ordinary field work of the Coast and Geodetic Survey, I am convinced that it would be of great utility in surveys to be plotted on large scales and with much attention to detail. I am inclined to think that the form of instrument to be used with the plane table (the tachygraphometer) would be especially useful in large-scale surveys, as in its use the elevations of numerous points could be rapidly determined without the use of a separate leveling instrument and contours of any desired interval could then be interpolated, while on the ground, with great precision and facility and without the danger of omitting details of form, to which surveys plotted in the office are liable.

In revising the paper for the record, in accordance with the request of the Conference, I have omitted those sections which contain the detailed directions for adjusting the various forms of these instruments and have changed the sequence of others, so that sections 33 and 34, which in the original appear as a supplement, immediately follow the

On the Wagner-Fennel Tachymeter and Tachygraphometer.

general discussion of the theory of the instrument. I have also omitted the letters of commendation, of which a considerable number are given, and which attest the high estimation in which these instruments are held by many European engineers.

W. C. H.

WASHINGTON, *April, 1892.*

A REVIEW OF THE TACHYMETER AND TACHYMETRY.

[By J. L. Lička, Engineer at Cassel-Wehlheiden.]

The great attention devoted in recent times to the tachymeter and tachymetry should justify this attempt at a concise but comprehensive description of the instruments and methods employed, a task undertaken by the author at the request of the publishers of the following treatises and carried out with the single purpose of systematizing our views on this subject.

In recent years, we denote by the name "tachymetry" that method of surveying which permits us to obtain the data, as to position and elevation, necessary for the determination of a point on the surface of the earth, by a single pointing upon the telemeter held at a desired point.

In this work the requirements are, rapid and sufficiently accurate measurement, accomplished with the least possible cost rather than with the most extreme precision.

These views are applicable, for example, in the preparation of general or special projects for the construction of roads, railroads and canals, or in working out plans in the domain of agriculture, as in the improvement of land, in joining detached pieces of ground, in the scientific management and utilization of forests, etc. Tachymeters and tachymetry, therefore, early attracted the attention of military and railroad authorities, who require surveys over large areas. For example, it should be noted that the tachymeter with anallatic telescope, invented by the engineer Porro at Milan in the year 1823, and called "clepscykel" or "cleps," was employed in 1835 in topographical surveys by the Piedmontese general staff.

The French engineer Moinot, in the year 1865, skilfully utilized Porro's distance measure in the construction of an instrument adapted to surveys, the tachymeter theodolite, furnished with a compass and with a vertical circle divided according to zenith distances; but he chiefly furnished methods for conducting the work of surveys, computations and mapping, which are to be considered standard, and which serve in great part as foundations for the further development of tachymetry.

Moinot's method, introduced into Austria in 1870 by the engineer Heuser, was employed there with great success in extensive delineation of very broken country. Since then, tachymetry has received

especial attention in Austria, particularly in the general office of Austrian railways at Vienna. Engineers, professors, and mechanicians compete in the construction of new instruments, in the improvement and elucidation of tachymetric surveying methods; all seek to put the engineer in a position to obtain his horizontal and vertical measurements in the shortest practicable time. In North Germany it is conceded that Moinot's method and tachymetry in general have found no greater employment than when about 1867 or 1868 a tachymeter was constructed by the engineer Carl Wagner, at that time in Wiesbaden, which seemed better adapted than other instruments for solving the familiar problems of tachymetry with the least expenditure of time and money; for most of the instruments made since 1871, the sole control of which for Germany had been transferred by the inventor to the mathematical instrument works of Otto Fennel at Cassel, were furnished to other countries, Turkey, Bulgaria, Roumania, etc., where they were used with the best results in studies for railroad locations. To the circumstance that since 1870, extensive preliminary works for railroads have every year become less frequent in North Germany, we may well attribute the fact that the above-mentioned tachymeter was less known than its simple manipulation and advantageous performance of work would lead us to expect. More recently, a change for the better is undoubtedly noticeable, magistrates and technicians engaged in the various fields of road building, of land improvement, and of forestry devoting to these instruments the attention they so well deserve, as is shown by the numerous testimonials to their capabilities.

In order to make perfectly clear the superiority and utility of the Wagner-Fennel instruments, we must state in the first place, at least in general outline, the characteristics of the instruments heretofore used. We shall consider only the most widely-used forms, whose optical distance-measures have wires of constant interval, and shall pass over those instruments more rarely used, in which the distance on the slope is determined by any other means. As already stated, the problem of tachymetry consists in determining in position and elevation, from certain stations, those points of the surface whose location seems desirable, by simply sighting upon the telemeter held at the desired points. The necessary data for this determination comprise the optical measurement of the inclined line of sight, and the measurement of a vertical and of a horizontal angle, which requirements are fulfilled in one way or another in every form of tachymeter. If, at first, we neglect the consideration of horizontal angles, which may be determined in three different ways, by theodolite, compass, or plane table, tachymeters may be classified as follows, according to the means used for determining the reduced horizontal distance and the relative or absolute height.

(1) Those instruments which, by optical distance-measures and vertical circles, furnish simply the data of inclined distances and vertical

angles, from which the horizontal distance of the foot of the rod from the center of the station and the relative height of the observed point from the horizon of the instrument are computed in one way or another.

(2) Those instruments in the use of which the length of the inclined line of sight measured by the distance wires of the telescope is converted at once into horizontal distance and relative or absolute height, by mechanical arrangements upon the surveying instrument, the so-called "projection apparatus."

As the characteristic feature of each of these classes—the vertical circle, and the projection apparatus—may be combined with the various instruments used for measuring horizontal angles, as the theodolite, the compass, and the plane table, six different instruments are possible under the two principal classes mentioned. Of these six instruments, the simple compasses and the plane tables are of subordinate value for measuring horizontal angles. The object of the survey will, in general, determine their use. The addition of sensitive compass needles to the theodolite and plane-table tachymeters will often be very convenient, for reasons which will be mentioned later. And therefore we need give no further separate consideration to compass instruments; because all that can be said of the theodolite tachymeter also finds its appropriate application to them.

There remain therefore to be discussed of the two categories of instruments above mentioned, (with vertical circles and with projection apparatus,) those which determine horizontal angles by the divided circle (theodolites) and those which represent them graphically (plane tables).

I. TACHYMETERS WITH VERTICAL CIRCLES.

The first subdivision of this group is represented by an instrument which will be designated simply as the tachymeter theodolite, and which, besides the usual arrangements for measuring horizontal and vertical angles, has a distance-measuring telescope. The observations which are made in the field on instruments of this class, for the determination of points to be located, give the distance on the slope and the horizontal and vertical angle, not counting as a separate observation the space subtended on the telemeter, from which the inclined distance is determined.

From these data the azimuth of the desired point is first determined, then the reduced distance and the relative height from the point of observation, as already mentioned, by computation or in any other way. It can not be denied that these preliminary computations or mechanical operations, as the case may be, even if conducted by experienced workmen, require considerable time and that the danger of introducing errors of computation, over which we have no control, is proportionately great.

For plotting the points of detail determined by tachymeter, the semicircular protractor proposed by Porro is most convenient. It differs from the usual form in having the graduation numbered from right to left, and in having upon the zero line a scale of distances, which renders it possible to lay down at once, according to scale, the points of detail, without using the compasses or marking the directions with lead pencil.

The above described operations, which refer to detailed surveys with the theodolite tachymeter, are also applicable, with some alterations, to surveys with the plane table and telemetric alidade.

In this case, with respect to the special manner of work with the plane table, *i. e.*, the graphical delineation of horizontal angles, the process of surveying undoubtedly shapes itself in a somewhat different manner than before, since the geometric picture of the surface to be surveyed is developed at once. In this case the line to the desired point is first drawn, then the distance on the slope is read from the telemeter, and finally the angle of elevation as before. Now it is absolutely necessary, for the tachymetric determination of a point, to compute at once in the field, or to determine by one of the methods suggested, at least the reduced distance, in order to be able to plot it upon the spot by compass and scale on the line drawn in the direction of the geometrical position of the point. It is also sometimes necessary to ascertain at the same time the relative heights of the observed points compared to that of the station, to compute the absolute height of the station, and to mark these at the geometrical positions on the map. Since the points surveyed are shown at once upon the plane table in correct position, this method has the great advantage over the use of the theodolite, as regards distribution of points, that during the work itself one obtains a clear idea of the surface to be surveyed and is unlikely to determine either too many or too few points. The cost of plane-table surveys will also, according to actual experience, prove lower than that of theodolite surveys. Therefore, whether considered from a theoretical or an economical standpoint, the plane table has advantages over the theodolite for tachymetric work. Only the fact that the theodolite gives the records of measurements in figures, which permits at any time a new drawing of the survey on any desired scale, while the results of plane-table operations, upon the perishable drawing paper, which is also much affected by the weather, are restricted to one determined scale, is in general to be advanced in favor of the theodolite in tachymetry. The theodolite has also material advantages over the plane table in regard to transportation, setting in position, and the work at the station itself; that is, as compared with the older forms of plane tables and alidades formerly used for cadastral surveys.

But the plane-table tachymeter appears in a much more favorable light, if instead of the old form of alidade we use, for example, an alidade provided with the Wagner projection apparatus shortly to be de-

scribed. When so equipped, plane-table tachymeters deserve full consideration, and will eventually supplant theodolite tachymeters in those cases where the object is to make surveys with little expense and a sufficient approximation to accuracy, and in surveys of a topographical character, where the object of the survey is satisfactorily attained in the production of the map itself.

II. TACHYMETERS WITH PROJECTION APPARATUS.

In these instruments also we distinguish two varieties according as they express horizontal angles in angular measure or by graphical delineation. Although different kinds of such instruments with projection apparatus have appeared, only the Wagner-Fennel tachymeters and tachygraphometers, as the best constructed, have succeeded in securing extensive use. As already stated, both forms of the instrument are so arranged that the horizontal distance and absolute height of the point to be determined are read directly from the instrument, after the simple pointing and certain intermediate manipulation, without moving the telescope and without any computation; while in the plane-table form (the tachygraphometer), the horizontal projection of the observed point is plotted in correct position on the plan by pressing an automatic needle arrangement.

The first of these instruments, the Wagner-Fennel tachymeter-theodolite—or, briefly, tachymeter—is a universal instrument in the true sense of the word, and may be advantageously used for tachymetric surveys, for minor triangulation, or for leveling.

In tachymetric detailed surveys with this instrument, four quantities are observed for the determination of each point, viz, the distance on the slope and, after the process of projection, the reduced or horizontal distance, then the absolute height, and finally the azimuth angle. The manipulation of the instrument in the field work is very simple and, after a certain amount of practice, proceeds very rapidly. The instrument is adjusted over the occupied station and the absolute height of the latter is set upon the scale of heights.

The determination of separate points from each station then proceeds as follows. The rodman sets the telemeter at the desired point, the observer at the instrument brings the middle wire upon the zero point of the rod, reads the space on the rod intercepted between the distance wires of the eyepiece, and records in his notebook the corresponding inclined distance. Then he sets off this inclined distance upon the rule parallel to the line of sight, pushes the projection angle against the vernier of heights, and from the latter reads the absolute height and from the horizontal rule the reduced distance of the observed point.

Finally, the horizontal angle is read off, in which one can generally limit himself to one vernier and to reading whole minutes. The read-

ing of the four quantities, the inclined and the horizontal distances, the height, and the azimuth take up about a minute and a half, or at the most two minutes of time, if the observer at the same time undertakes the necessary settings and the record of the results of the measurements and if only one rod is used.

The performance of work can, however, in proportion to experience, be materially increased if two observers work with one instrument and at the same time employ two rodmen. In consequence of this, the engineer conducting the sketching, who thoroughly understands at the same time the management of the survey, must develop a correspondingly high production of work if desirable results are to be obtained from all persons employed.

From the preceding remarks it ought not to be difficult to draw the conclusion that the Wagner-Fennel tachymeter-theodolite is superior to the ordinary instruments of its class, and we believe our views will be supported by the unanimous opinions of all those who have made extensive surveys with both kinds of instruments. As regards the second characteristic instrument of this class, the Wagner-Fennel tachygraphometer, we can make a brief reference to what has already been said, and enter into an account of the instrument alluded to only so far as necessary for the comprehensive description of the tachymeter. All necessary explanations in regard to setting up this instrument will be found in § 25 of the following treatise.

The survey itself is conducted in the same way as with the theodolite-tachymeter, except that the horizontal distance of the observed point is not first read off, but is plotted directly upon the plane-table sheet by an automatic attachment with movable needle, and in true relative position, according to scale. At the geometrical position of the point thus obtained we mark its absolute height, read directly from the instrument.

As regards rapidity of work, the tachygraphometer even surpasses the theodolite with projection apparatus, for according to the statements of a professional man certainly in this respect most noteworthy, the inventor himself (Carl Wagner, "Ueber die Hilfsmittel der Tachymetrie, insbesondere über die Vorzüge der schiefen Lattenstellung." Zeitschr. f. Verm., Bd. xv., Heft 14 u. 15), the field work with the tachygraphometer takes no longer and, all things considered, less time than with the theodolite or with any other instrument adapted to tachymetric surveys, since with the tachygraphometer we obtain the reduction of the inclined distance as well as the plotting of the desired point, directly, as an immediate result.

III. TACHYMETRIC SURVEYS.

With special reference to tachymetric surveys, we need not, in considering the numerous monographs, articles in periodicals, and handbooks of surveying, pursue the subject further than appears desirable

for explaining the manipulation and advantageous use of the Wagner-Fennel instruments. For further information we may chiefly refer to the excellent general account in Jordan's Handbuch der Vermessungskunde, Stuttgart, 1877, Bd. I, S. 626 ff., which we here for the most part follow in essential points.

The field work of tachymetry consists, as already stated, in determining, by measurements of distance, azimuth, and height, the points desirable for the actual object of the survey from certain other points which serve as stations for the tachymeter.

To determine the positions and altitudes of the tachymeter stations we may employ any of the exact methods of horizontal and vertical measurement, as triangulation, in connection with trigonometric leveling, or the regular system of traversing in polygons in connection with spirit leveling, or we may simply connect the single stations with each other by tachymeter.

These are in general the extreme methods, which, however, may be combined in various ways so that, according to the greater or less pains taken in the accurate determination of the stations, a correspondingly different degree of precision will be attained in the elements determining their position and height.

A scheme of minor triangles, with simultaneous trigonometric leveling, cannot always be laid out, especially in extended forests, with figures sufficiently small to furnish in this way all necessary stations for the tachymeter; one is often compelled to lay out a string of main figures and others of subordinate importance, in order thereby to first obtain principal stations with which other approximate stations may be connected by tachymeter. Whether, in such a series or main scheme, the relative heights should be determined by level or by vertical angles depends chiefly upon the amount of the relative differences of height between the stations directly connected; in flat or rolling country leveling is advisable on account of its exactness, but in mountainous regions, with constant changing of instrument and short sights, leveling no longer commends itself, and we then measure the vertical angles for all the lines (preferably in both directions), at the same time with the measurement of horizontal angles.

The principal differences of height are best computed exactly, by logarithms, in connection with the computation of the coördinates of the points of the polygons, and the possible errors of closing are distributed in the connected series on both sides in proportion to the lengths of lines. In steep mountainous country, one is frequently compelled to run out the traverses of the sides of the polygons with the tachymeter.

A series of polygons with leveled stations commends itself, then, for the tachymetric survey of the ground, if it is a question of the survey

of a strip of country from 200 to 500 metres wide for laying out a railroad, a road, or a canal.

In this case, using a general preliminary outline prepared upon the basis of previous topographic maps and careful reconnaissances, we trace out in the field a series of polygons (primary series, called also basis of operations) lying near the most probable location. Since we can read from the separate stations up to 300 metres distance with the telemeter the single stations of the series may be as much as 600 metres apart, which would be perfectly practicable and useful in entirely flat country, but in the mountains the mean distance between any two stations must generally be much smaller; distances of from 200 to 400 metres should be the rule under mean conditions.

The scale divisions of the Wagner-Fennel instruments are arranged for distances up to 200 metres, with the assumed scale of 1–1000, which does not, however, prevent working at greater distances, though it appears inexpedient to do so.

The different stations of the series of polygons are of course so selected that one can see from any one of them the preceding and following stations and can on all sides overlook as much as possible of the strip of country to be surveyed.

After the selection and careful marking of the principal points, the lines are measured in both directions of the series and the horizontal angles at least twice in each position of the telescope; then the entire series is twice leveled, and from these observations the coördinates and heights of the separate stations of the chain are computed.

If we obtain the horizonal orientation by a simple traverse, sighting on the last station, we do not use the compass, strictly speaking, at all, but we can employ it for reading off the approximate azimuth, which is of material advantage for a general check on the plotting. For the purposes of the detailed survey, field sketching sheets are prepared, showing the series of polygons plotted in the usual way by rectangular coördinates; then the detailed survey can proceed upon a secure foundation by means of the simple tachymeter and without further difficulty.

If one does not in the first place systematically determine and mark the primary stations, but merely connects the different stations with each other tachymetrically, generally without marking them, one should at all events measure all the connections between every two points in distance, azimuth, and height, reciprocally in both directions, and thus obtain a control in the field, so as not to run the risk that through an error in the connection of two stations all the work which is done at one or more stations should be lost. The series of polygons which connects the stations should not be left unchecked. Such a series not selected in the beginning, and hence not commonly marked, should therefore, at all events at the end of the work be verified by separate

measurement (for example, by the three point problem or back intersections from at least two compass bearings).

As concerns the survey of details, the most important points have already been discussed in connection with the use and manipulation of the tachymeters in question.

The selection and the number of points to be determined will vary with the character of the country and the degree of precision required, which in turn is governed by the object of the survey.

With regard to the plotting of tachymetrically determined points, and also the further elaboration of tachmetric surveying, which is all conducted in the same way as in the use of an ordinary theodolite (engineer's transit), the following works may be referred to:

Jordan, Handbuch der Vermessungskunde, Band I. Stuttgart, 1877.

Werner, Die Tacheometrie und deren Anwendung zu Tracestudien. Wien, 1883.

Heusinger von Waldegg, Handbuch der Ingenieur-Wissenschaften, Band I. Leipzig, 1883.

Hartner-Wastler, Handbuch der niederen Geodesie. Wien, 1885.

With regard to the precision of optical measurement of distances, the following is also well worthy of attention:

R. Wagner, Ueber die mit dem Reichenbach'schen Distanzmesser erreichbare Genauigkeit und einige Erörterungen über die Fehlerursachen desselben. Zeitschrift für Vermessungswesen, Band XV. Heft 3, 4, 5. Stuttgart, 1886.

INTRODUCTION.

With the instruments commonly used in tachymetric work—theodolites with telescopes arranged for measuring distances and with vertical circles for determining heights—it is necessary to compute the coördinates of the point at which the rod is held from the distance on the slope, obtained from the space subtended on the rod.

The instruments hereafter described aim at a saving of these time-consuming computations by giving a direct reading from the instrument of the coördinates of the point observed upon.

The length of the inclined line of sight is measured by means of the distance wires of the eyepiece, and then the horizontal distance from the center of the station to the foot of the rod and the absolute elevation of the same above sea level are read from the instrument, without any computation; or in a similar way, when using the plane-table form of the instrument, the horizontal projection of the observed point is pricked upon the drawing in its correct position by pressing down a needle suitably arranged.

Thus in tachymetric work, horizontal angles may be measured in three different ways—by theodolite, by compass, by the plane table—and hence three different constructions of this tachymeter are provided.

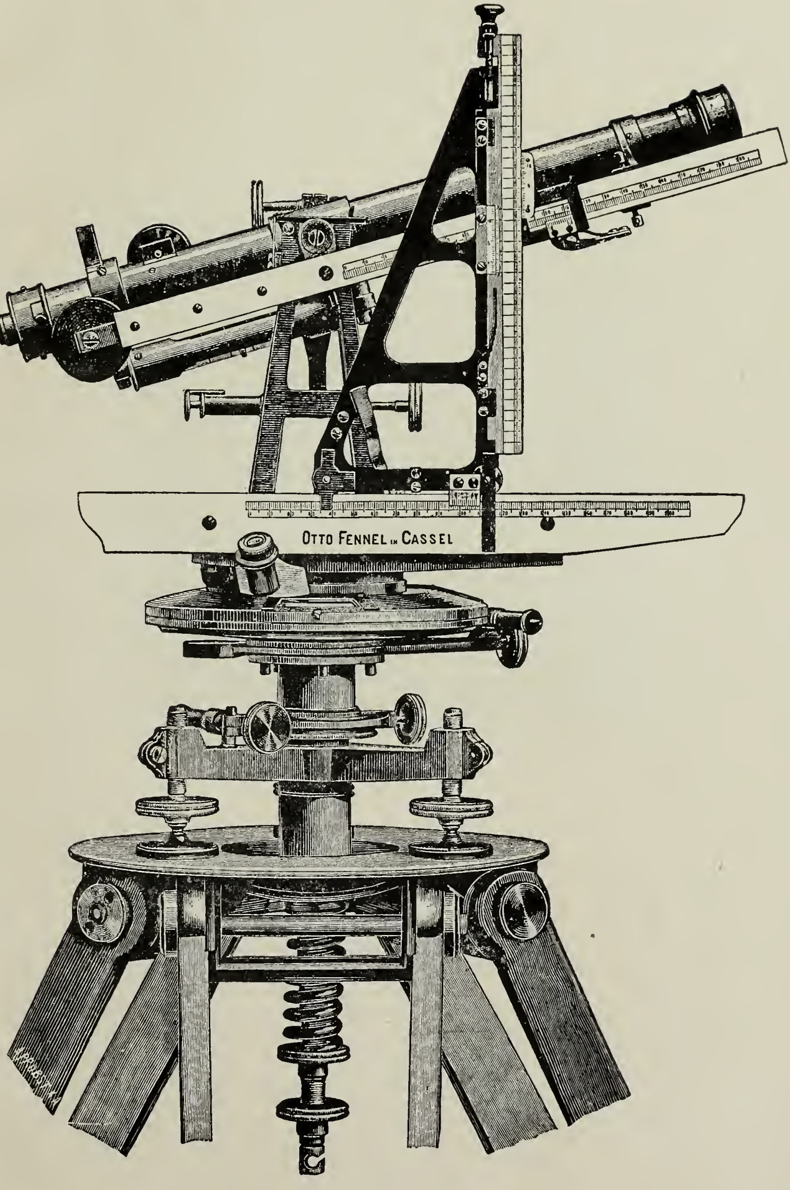
The same characteristic, the Wagner projecting apparatus, is common to all, and, therefore, in the following pages the description and theory of this projecting apparatus are first given.

THE PROJECTING APPARATUS, ITS THEORY AND MANNER OF USE.

SECTION 1. To the telescope of the tachymeter, which is provided with distance wires, a rule AA (illustration No. 32), bearing a scale of distances, is attached by two arms, one of which is fixed to the axis of the telescope outside of the bearing and the other near the objective and so that the straight upper edge and the face of the rule are parallel to the vertical plane in which the telescope moves in altitude. In any position of the telescope the upper edge of the rule has exactly the inclination and direction of the line of sight. Upon this rule moves a slide S, held in place by an automatic spring clamp, and carrying two verniers. The upper vernier a serves for reading from the scale of heights DE of the projection angle, when the latter is pushed against the contact edge of the vernier. But in order to be able to do this with any inclination of the rule, the vernier a is capable of rotating on an axis which, as is easily proved, must lie exactly in the contact edge. Therefore, in any inclined position of the rule the vernier a may be made parallel to the scale of heights; that is, vertical. The lower vernier b remains fast to the slide and is used for the exact setting of the inclined distances, in reduced scale, upon the rule. If the zero point of this vernier be set at the zero point of the scale, the axis of rotation of the vernier a lies in the prolongation of the axis of rotation of the telescope.* Therefore in any other position of the slide, the interval at right angles between the two axes may be read from the scale, or, conversely, any desired value may be given to this interval by setting the slide.

SEC. 2. Nearly perpendicularly below the rule just described is a second rule BB, also provided with a scale of distances and so attached that its face is parallel to that of the upper rule and that its upper edge remains horizontal. Upon this upper edge, which is always horizontal when the instrument is in use, is placed a movable right angle CDE, upon the vertical edge of which is a scale for reading heights, which scale can be moved vertically about 1·5 centimetres, by the micrometer screw E. In any given position of the right angle, this scale of heights is in the same vertical plane as the vernier a. The numerical values for this scale are written with lead pencil for every 10 units upon a small strip of ivory, and when the height of the station is changed are easily erased and replaced by others. Thus the same result is attained as by a great motion of the scale itself, while the exact setting to single

* As will later be shown in section 6, the position of the vernier b is actually slightly different. Nevertheless in sections 3 and 4 the above statement is retained for the sake of simplicity.



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units and fractions is accomplished by means of the micrometer screw *E* and the vernier *d*. For example, if the scale is to be set for a given elevation of 237·40, we mark one of the even tens nearest to the zero of the vernier *d* 230 (Fig. *a*), and then by the screw *E* move the whole scale until the vernier reads 7·40 units, in addition. With the telescope horizontal, both verniers, *d* and *a*, then give the same height, 237·40 (Fig. *b*).

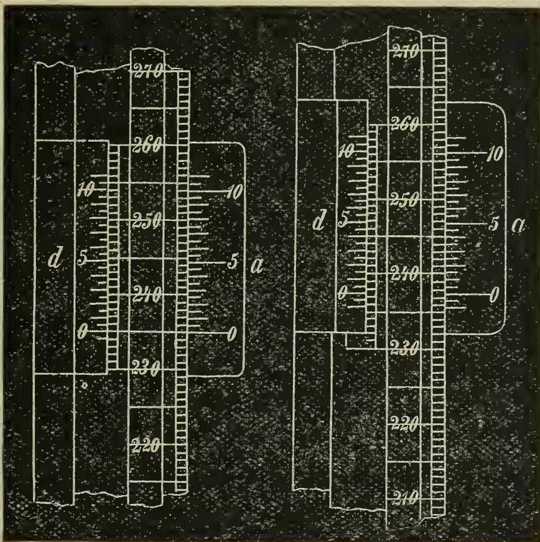

FIG. *a*. FIG. *b*.

In order to facilitate the sliding motion of the projection angle, the ends of its lower surface *CD* are supported on friction rollers. Then at *i* is an automatic spring clamp by which the projection angle is held fast in any position, and finally at *c* is a vernier which serves for reading the reduced horizontal distances. When this last vernier is set at zero on the scale *BB*, the forward edge of the scale of heights *DE* is exactly in the vertical plane passing through the horizontal axis of the telescope. If, therefore, the projection angle is pushed forward until the scale of heights meets the contact edge of the vernier *a*, the horizontal projection of the distance between the axis of the vernier *a* and the horizontal axis of the telescope may be read directly from the vernier *c*, and the vertical projection of this distance appears on the scale of heights as the difference of the verniers *a* and *d*.

SEC. 3. In order to explain the theory and use of this projection apparatus, let us imagine two straight rules lying in a vertical plane and capable of rotation about a common point *O* (fig. c.), the upper edge *AA* of the one being directed by a sighting arrangement upon a point *P*, to be determined, while the upper edge *BB* of the other is retained

in horizontal position by a level. Then if the length Oa corresponds in any known relation (reduced scale) to the distance OP, and if, further, CDE be a right angle (projection angle) movable upon BB, then

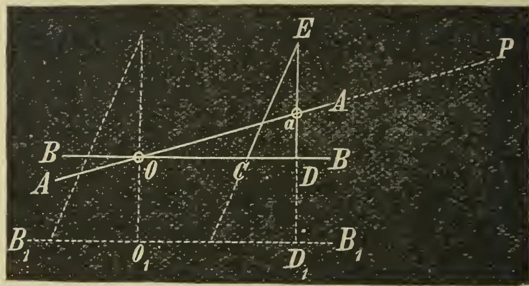

FIG. c.

OD is evidently equal to the horizontal projection and AD to the vertical projection of Oa and only the arrangement of suitable graduations is necessary in order to be able to read these values directly with satisfactory exactness.

If the second rule, while still in the vertical plane of the first, instead of remaining at BB is brought into any desired position parallel to BB, as B_1B_1, we still preserve (with a correspondingly lengthened projection angle) the horizontal and vertical projections of Oa, for from the resulting parallelogram, $OD=O_1D_1$ and $aD=aD_1—DD_1=aD_1—OO_1$.

The distance $OO_1=DD_1$ only comes into consideration in vertical projection, and always as a constant correction, the subtraction of which can be mechanically performed, if this distance, the relative height of the point of rotation O, is marked on the projection angle.

If, for example, the zero point of the graduation upon the projection angle stands at the same height as the point O, then the former also corresponds with the point D; and Da (in the same way the relative height of the point P sighted upon) can be read directly from the graduation in correspondingly reduced scale.

SEC. 4. If we add the relative height of P to the absolute height of the point O, referred to any horizontal plane, we shall obtain the absolute height of the point P. But this addition is not obtained by computation but by mechanical means, assigning to the point O the absolute height of the station. Then the point D on the scale of heights corresponds to the absolute height of the station and by reading off at a, the addition of Da is accomplished without separate manipulation, and therefore the absolute height of P is obtained. Hence it does not enter into consideration whether P lies above or below the horizon, for in the latter case a subtraction of the relative height follows, as is easily indicated by a corresponding alteration of the figure.

The procedure necessary for moving the scale of heights in setting for the absolute height of the station is given in section 2, above.

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Finally, it should be suggested that the points O and a are understood to represent the geometrical axes of revolution of the telescope and of the vernier a.

Sec. 5. In the use of a tachymeter-theodolite, whose telescope is arranged for the use of the telemeter and with the rod held at right angles to the line of sight, we obtain, as is well known, the horizontal distance E between the foot of the rod and the station point by the formula,

$$E = (C.L + c) \cos \alpha + S. \sin \alpha \qquad . \ . \ . \ . \ (1)$$

in which, L is the interval read from the rod,

C is the constant factor, as 100 or 200, for example,

c the additive constant, equal to the distance from the center of the instrument to a point at a distance in front of the objective equal to its principal focal distance,

α the angle which the central visual ray makes with the horizon,

S the height of the target above the ground.

It will now be shown that we obtain from the tachymeter with projection apparatus a similar graphical derivation of this formula and the process by which it is found will be given.

The addition of the constant c to the product CL, which is easily obtained from the rod-reading and set off upon the scale AA by means of the vernier b, is accomplished always in a mechanical way if the vernier b is so corrected, once for all, that it reads $-c$ when the contact edge and axis of revolution of the vernier a lie in one vertical plane with the horizontal axis of the telescope.

Then also in the corresponding position of the projection angle the vernier c stands at zero upon the lower scale, from which the reading of the horizontal projection is taken, while in any inclined position of the telescope one will read a horizontal distance which is greater by $c \cos \alpha$ than would be the case without this correction. The actual amount of this correction must evidently be equal to $\frac{c}{n}$, if n denotes the reduced proportion of the scale.

Sec. 6. In order also to bring the term $S. \sin \alpha$ into calculation by mechanical means, the axis of rotation of the vernier a is so arranged that in the horizontal position of the telescope it lies below the horizontal axis of the telescope at a distance equal to $\frac{S}{n}$. If this condition is satisfied, not only is the term $S. \sin \alpha$ brought into consideration in taking off the projection, but we also obtain the height of the distant point compared to that of the station, correctly within the limit $J-S$ (where J is the height of instrument above ground and S that of the target).

Figure *d* serves as a demonstration, and in this figure

V denotes the zero point of a telemeter at P,

O denotes the horizontal axis of the telescope,

OV denotes the line of sight (determined by the middle wire) to which the telemeter is held perpendicular,

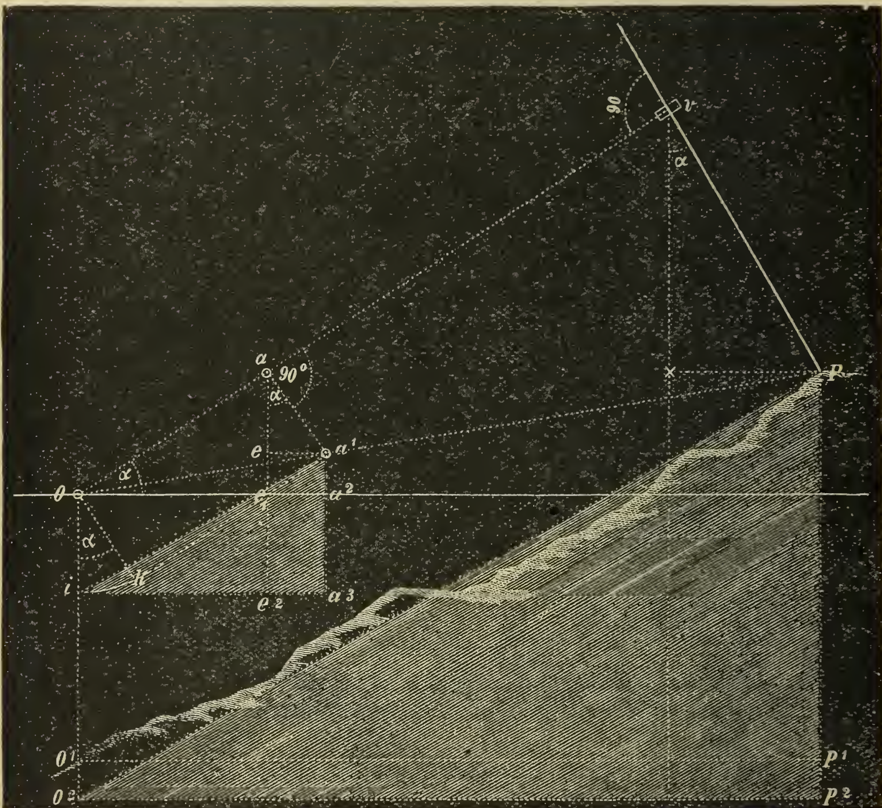

FIG. *d*.

α denotes the angle of inclination of this line of sight to the horizon, and

$\frac{1}{n}$ denotes the reduced scale of the divisions on the rules;

further let

$OO_1 = J =$ the height of instrument, *i. e.*, the vertical distance from the axis of the telescope to the ground.

$PV = OO_2 = S =$ the height of the signal, *i. e.*, the distance from the foot of the rod to its zero point,

$$Oa = \frac{OV}{n}.$$

On the Wagner-Fennel Tachymeter and Tachygraphometer.

If we now draw aa at right angles to OV, and also make $aa_2 = Ok = Oi = \frac{S}{n}$, ka will represent the line, parallel to the line of sight, in which the point of rotation of the vernier a (section 1, illustration No. 32) moves when the slide is moved along the rule. When the distance is zero and the line of sight horizontal, this point of rotation of the vernier falls upon i.

For the distance on the slope, OV, the setting of the vernier b (section 1, illustration No. 32) to $\frac{OV}{n} = ka_1$ gives on the rule AA the point a_1 and the distance Oa_1 must evidently, from the similarity of the triangles Oa_1a and OPV, be equal to $\frac{OP}{n}$. If now Oa_1 be projected upon the horizontal, we obtain the length.

$$Oa_2 = ia_3 = Oe_1 + e_1a_2 = Oa.\cos\alpha + aa_1 \sin\alpha = \frac{OV}{n}.\cos\alpha + \frac{S}{n}.\sin\alpha$$
$$= \frac{1}{n}\Big[(C.L + c)\cos\alpha + S.\sin\alpha\Big] = \frac{1}{n}E$$

By this process then we obtain the horizontal projection of the distance OP, in the reduced scale adopted, corresponding to the formula (1), section 5.

SEC. 7. The difference of height between O_1 and P is $PP_1 = H$. If we suppose that in Fig. d, $OO_2 = VP = S$ and that the connecting right lines ia_1 and O_2P are drawn, then the figures Oia_1a and OO_2PV are similar, whence it follows that ia_1 is parallel to O_2P and that $ia_1 = \frac{1}{n}.O_2P$.

Further, it appears from the similarity of the triangles ia_1a_3 and O_2PP_2, that $a_2a_3 = \frac{1}{n}PP_2$; that is to say, from the vertical projection of the point a_1 we obtain in a_1a_3 the reduced measure of PP_2.

If this be converted into the natural scale and if $J-S$ be added thereto, we then obtain the difference of height between O_1 and P;

$$H = PP_2 - P_1P_2 = PP_2 - (S - J) = PP_2 + (J - S)$$

But the addition of $J - S$ can also be made in a mechanical way upon the instrument, as long as one works with a constant height of instrument.

If one takes the height of instrument equal to that of the signal (the height of the zero point of the rod), which always amounts to $1{\cdot}5^m$, then $J - S = 0$, and this correction is in general unnecessary. If, however, the height of instrument is not equal to that of the signal, then we bring the difference $J-S$ into account by so moving the vernier d, when the telescope is horizontal, that its reading upon the scale of

heights differs from the vernier a by $\frac{J-S}{n}$. With a negative value for $\frac{J-S}{n}$ the vernier d must be moved up and with a positive value it must be moved down.

The vernier d is attached to the projection angle by two small screws passing through elongated slots so that it may be moved in a vertical direction, if the screws are loosened a little.

If, for example, the assumed instrument height of $1{\cdot}5^{m}$ were too great, on account of an observer's smaller stature, and were reduced to $1{\cdot}25^{m}$, consequently $J - S = -0{\cdot}25^{m}$, and the vernier d must be moved up $0{\cdot}25^{mm}$ if n=1000, and thence $\frac{J-S}{n} = -0{\cdot}25^{mm}$.

If, then, the scale of heights be set for the height of the particular station by the vernier d and the height of the observed point be read from the vernier a, the latter value will be smaller by $0{\cdot}25^{mm}$, (corresponding on the scale used to $0{\cdot}25^{m}$), than would have been the case without this correction. Should it for any reason be impracticable to work with a constant height of instrument, the difference $J-S$, which for any one station is a constant, could be allowed for in setting the scale of heights to the absolute height of the station.

If, for example, the height of the station is $254{\cdot}6^{m}$ and the height of instrument is $1{\cdot}3^{m}$, then $J - S = 1{\cdot}3^{m} - 1{\cdot}5^{m} = -0{\cdot}2^{m}$ and therefore the height assigned to the instrument in setting the scale of heights is $254{\cdot}4^{m}$. If one prefers not to use this method, the difference $J - S$ is to be added algebraically in the usual way to the height of the observed point, read from the vernier a.

SEC. 8. (Superseded by the addendum given in the regular order, but translated here for comparison.)

It follows, from the description and theory, that the use of the projection apparatus consists simply in this, that the slide with the vernier b is set at the graduation corresponding to the distance read off, then the projection angle is pushed against the vernier a, when the height and distance horizontally of the point sighted upon are read from the verniers a and c, respectively.

If one has read a distance on the rod for which the graduation of the scale is insufficient, one divides the distance into two parts, reads the height and horizontal projection for each part, and adds these together. For example, if the distance read is $287{\cdot}3^{m} = 200^{m} + 87{\cdot}3^{m}$, we set off, first, upon the upper rule 200^{m}, read the corresponding height and horizontal distance, then set off $87{\cdot}3^{m}$ upon the upper rule, read also the height and horizontal distance corresponding to this distance, and add the numbers so obtained, and thus obtain the coördinates of the point sighted at. A consideration of Fig. e, in which D, H, E denote the entire inclined distance, the height and the horizontal projection,

On the Wagner-Fennel Tachymeter and Tachygraphometer.

and d_1, d_2, h_1, h_2, e_1, e_2, denote the corresponding partial distances and heights, respectively, will at once show the correctness of the rule.

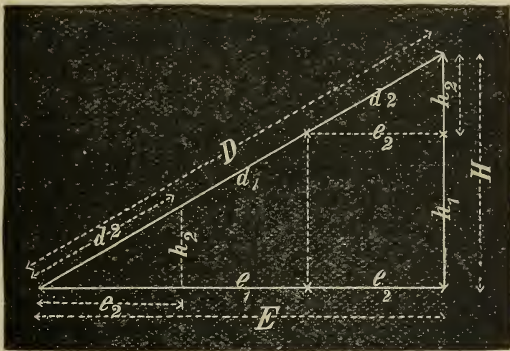

FIG. *e*.

SEC. 9. In cases where it is not practicable to hold the rod at right angles to the line of sight, it may be held vertically. Then the inclined distance is read as usual, set off upon the upper rule, the corresponding horizontal projection read off, this last distance set off once more upon the upper rule and projected the second time, and we then obtain the desired horizontal projection of the point sighted upon. If in the vertical position of the rod the inclined distance was found equal to D, then its horizontal projection is evidently $E = D. \cos^2 \alpha$.

But one obtains exactly the same result by the double projection.

In Fig. *f*, let $Oa = \frac{D}{n}$, then $Ob = Oc = \frac{D}{n} \cos \alpha$, the first projection of $\frac{D}{n}$.

Exactly in the same way $\frac{E}{n} = Oc \cos \alpha = \frac{D}{n} \cos^2 \alpha$, which agrees with the form given above.

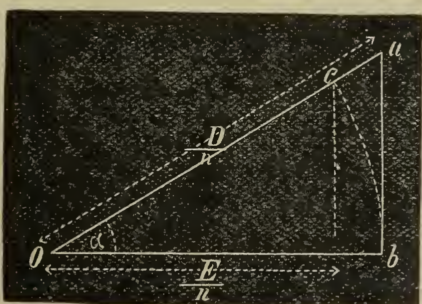

FIG. *f*.

NOTE.—Sections 8 and 9 of this treatise have been superseded by the following addendum:

COMMUNICATION FOR THOSE USING THE WAGNER-FENNEL TACHYMETER AND TACHYGRAPHOMETER.

CASSEL, *May 16, 1890.*

OTTO FENNEL,

Mathematical and Mechanical Institute, Cassel:

In the treatise, "Die Wagner-Fennel'schen Tachymeter des Mathematischen Mechanischen Institutes von Otto Fennel, in Cassel, 1886," there are in sections 8 and 9 some inaccuracies concerning the use of the Tachymeter at distances over 200 meters and in the use of the rod held vertically. It is therefore necessary in these cases to proceed with the survey *not* as stated in sections 8 and 9, but according to the following rule. The detailed proof of this rule, as well as a new demonstration of the theory of the projection apparatus, will shortly be made known in Appendix II:

I.

In order to project a distance which is greater than 200 metres and less than 400 metres, one sets off upon the telescope rule the half of this distance, reads off the corresponding horizontal and vertical projections E_1 and H_1, doubles them, sets at zero on the telescope rule, reads once more the corresponding horizontal and vertical projections e_1 and h_1, and subtracts the same from the values $2E_1$ and $2H_1$.

Example.

Height of station=47·8m. : z=0·1m. : Ar=47·7m.

Rod readings { Upper wire at the zero point.
Middle wire at 1·836 (check reading).
Lower wire at $3·673 \times \frac{1}{2} = 1·8365$.

Setting on the telescope rule = half distance = 183·65m.

Horizontal projection.	Vertical projection.
$E_1 = 181·45$	$H_1 = 52·10$
$2\ E_1 = 362·90$	$2\ H_1 = 104·20$
$-\ e_1 = -0·85$	$-\ h_1 = -47·80$
$E = 362·05$	$H = 56·40$
True horizontal distance.	True difference of elevation.

II

If one has observed upon the rod held vertically, he obtains the horizontal and vertical projections of the distance by setting off the observed rod-reading upon the scale attached to the telescope, by reading its horizontal projection E_1, by setting off this reading again upon the telescope scale, and by reading off the corresponding horizontal projection E_2 and vertical projection H_2. Next one sets at zero on the telescope scale, reads off the horizontal projection e_1, subtracts there from the additive constant c, sets off $e_1 - c$ upon the telescope scale,

On the Wagner-Fennel Tachymeter and Tachygraphometer.

and reads the corresponding horizontal projection e_2 and vertical projection h_2. Now one subtracts e_2 from E_2 and h_2 from H_2, and adds to the latter value the reduced height of station, Ar.

Example.

$c = 0{\cdot}5$ m for all Wagner-Fennel tachymeters

Height of station $= A = 51{\cdot}65$m : $z = 0{\cdot}05$: $A - z = 51{\cdot}60$.

Rod reading $\begin{cases} \text{Upper wire, zero,} \\ \text{Lower wire, } 1{\cdot}729. \end{cases}$

Setting on the telescope scale $= 172{\cdot}9$ m.

Horizontal projection.			Vertical projection.	
$E_1 =$	165·65		$H\,2 =$	102·15
$E_2 =$		158·75	$-\,h\,2 =$	51·70
$e_1 =$	1·05		$+\,(A - z) =$	$+$ 51·60
$e_1 - c =$	0·55			
$-\,e^2 =$		$-$ 1·50	True height $H =$	$+$ 102·05
True horizontal distance $E =$		157·25		

Appendix containing the derivation of the formula assumed as known in sections 5 and 9.

SEC. 33. The distance-measuring telescopes of the Wagner-Fennel tachymeters do not differ materially from those commonly employed in geodetic instruments, except that the diaphragm carries, besides the usual cross hairs, two additional parallel horizontal wires (distance lines), one above and one below the central horizontal line, and at equal distances from it.

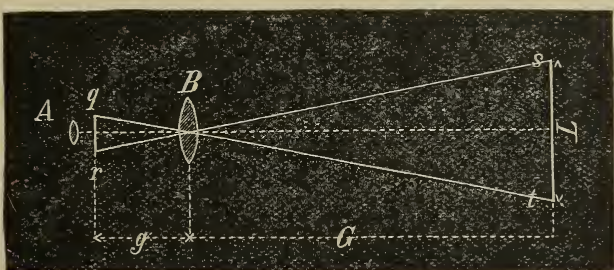

FIG. *g*.

In Fig. *g*.

A is the eyepiece;

B, the objective of a tachymeter telescope;

f, the focal length of this objective;

$l = q\,r$, the portion of the plane of the image included between the two distance wires;

L, the portion of a telemeter which is intercepted between the two planes of rays $q\ t$ and $r\ s$ passing through the distance wires, and further;

G, the distance of the telemeter from the objective;

g, the distance of the image from the objective, and consequently

$$\frac{L}{G}=\frac{l}{g} \quad \ldots\ldots\ldots\ldots \quad (1)$$

According to a fundamental equation of optics we have also

$$\frac{1}{G}+\frac{1}{g}=\frac{1}{f} \quad \ldots\ldots\ldots\ldots \quad (2)$$

By means of these two equations the desired distance G may be deduced from L, l, and f, which are assumed to be known, in the following manner:

From equation (1) $\frac{1}{g}=\frac{L}{G.l}$

If we substitute this value in equation (2) we have

$$\frac{1}{G}+\frac{L}{G.l}=\frac{1}{f}$$

Multiplying both sides by $G.f$ and transposing, this becomes

$$G=f+\frac{f}{l}\,.\,L \quad \ldots\ldots\ldots \quad (3)$$

The value $\frac{f}{l}$, by which the part of the rod appearing between the wires is to be multiplied, forms the so-called multiplication constant, which is hereafter denoted by C, and by the introduction of which equation (3) takes the following form:

$$G=C\,.\,L+f \quad \ldots\ldots\ldots\ldots \quad (4)$$

in which G denotes the distance of the rod from the objective.

In order now to obtain the distance from the center of the instrument to the rod, hereafter denoted by D, the distance i from the horizontal axis of the telescope to the objective is to be added to every distance. Equation (4) then becomes

$$D=C\,.\,L+f+i \quad \ldots\ldots\ldots\ldots \quad (5)$$

The amount $f+i$ denotes the distance of the forward principal focus of the objective from the center of the instrument, the so-called addition constant, which is generally denoted by c. If we introduce this value in equation (5) it becomes

$$D=C\,.\,L+c \quad \ldots\ldots\ldots\ldots \quad (6)$$

SEC. 34. We have next to investigate the method by which, with the line of sight inclined to the horizon and with the telemeter held at right angles to the line of sight, we obtain the horizontal projection E

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of the distance on the slope from the centre of the station to the foot of the rod. For this we use Fig. *h*, in which

O denotes the center of the instrument;

V the zero point of the telemeter;

P the foot of the same;

L the space on the rod intercepted between the distance wires, and α the angle of inclination which the central ray $O\ V$ makes with the horizon.

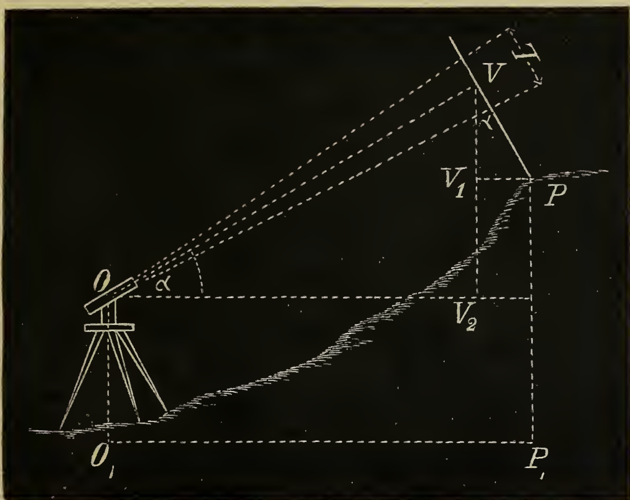


FIG. *h*.

If in addition we call the horizontal projections of the points O, V, and P, respectively, O_1, V_1, V_2, and P_2, and the distance from the zero point to the foot of the rod S, the desired distance $O_1\ P_1$ is easily obtained, as follows, from equation (6) of section 33:

$$O\ V = C.\ L + c$$

and therefore

$$O\ V_2 = (C.\ L + c.) \cos \alpha$$

and

$$V_1\ P = S. \sin \alpha.$$

Adding these last two equations and considering that

$$O\ V_2 + V_1\ P = O_1\ P_1 = E,$$

we obtain

$$E = (C.\ L + c) \cos \alpha + S. \sin \alpha \quad . \quad . \quad . \quad (9)$$

This is the formula given in the beginning of section 5, upon which is based the discussion in sections 5 and 6.

In section 9 we have discussed the case where the condition of the ground constrains us to depart from the customary position of the rod at right angles to the line of sight and to hold it vertical.

This case is shown in Fig. *i*, in which O, O_1, V, P, P_1, L, $s\ t$, have the meanings already assigned them in sections 33 and 34.

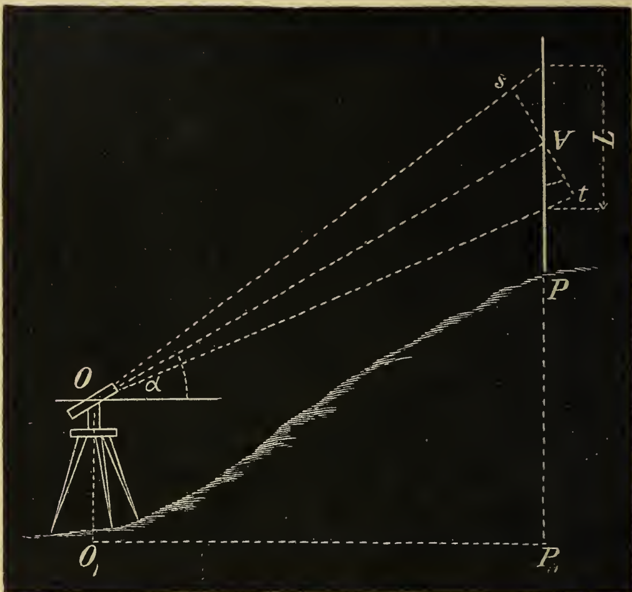


FIG. *i*.

$$s\ t = L.\cos\alpha$$

and therefore

$$O\ V = C.\ L.\cos\alpha + c \quad \text{. . . . .} \quad (10)$$

or approximately

$$O\ V = (C.\ L + c)\cos\alpha \quad \text{. . . . .} \quad (11)$$

(With $c = 0{\cdot}5$ m. and $\alpha = 10°$, the difference between formulas (10) and (11) amounts to 0·005 m., with $\alpha = 25°$ to 0·045 m., with $\alpha = 45°$ to 0·145 m).

If, as in equation (6) of section 33, we denote the factor $(C.\ L + c)$ by D, equation (11) assumes the form

$$O\ V = D.\cos\alpha \quad \text{. . . . .} \quad (12)$$

If now we once more denote by E the horizontal projection $O_1\ P_1$ of $O\ V$, we obtain

$$\begin{aligned} E &= O\ V.\cos\alpha \\ &= D.\cos^2\alpha \end{aligned}$$

as the formula, the graphical demonstration of which by the projection apparatus was explained in section 9.

DESCRIPTION OF THE TACHYMETER WITH REPEATING CIRCLE.—(Tachymeter-theodolite.)

SEC. 10. The construction of the tachymeter with repeating circle is shown in a general way in illustration No. 32. The telescope is of 35 centimetres focal length and has a magnifying power of 31. It has cylindrical pivots resting in Y-shaped bearings, can be easily moved and reverses by the eye end. The covers of the bearings have openings so arranged that a striding level can be placed upon the pivots, for the horizontal adjustment of the telescope axis. In order to be able also to take exact levels, a reversion level is attached to the telescope.

The reticule for telemetric measurements is of peculiar construction and so arranged that either of the two outer wires may be brought up to the middle wire.

The horizontal circle, of 15·5 centimetres diameter at the inner edge of the limb, is provided with a cover, in order to perfectly protect the graduation from defacement and from flying dust. The openings for the verniers are covered with glass plates. The graduation is made, as desired, either sexagesimal (360°) to 20′, with verniers reading to 30″; or centesimal (400°) to 50′, with verniers reading to 1′. The axes are of the most perfect construction. The clamps act on the center without touching the circle or the alidade and the slow motion is given by fine-threaded screws, working against springs. The castings are all large and ribbed, in order to obtain the greatest stiffness combined with moderate weight. The fastening of the instruments to the stands is by means of screw bolts. The stands are of a special, new construction. The tripod head consists of a single bronze casting and is therefore of the greatest durability, while the legs are made of the best tough ash. These stands considerably surpass in stability those earlier used, without having a greater weight. The fastening of these instruments in their boxes is so secure that the longest and most severe transportation has no bad effect upon them.

DESCRIPTION OF THE TACHYMETER-COMPASS.

SEC. 18. The tachymeter, for the measurement of horizontal angles by compass, is in its upper construction almost exactly like the one previously described; only the bearings of the telescope axis are different. These have pivots shaped like double cones, which lie in bearings closed by solid covers and therefore can not be taken out of the bearings.

The compass has a needle 11.5 centimetres long and the circle is divided to half degrees. The north and south line is parallel to the plane in which the telescope moves. Upon the compass plate are fastened at right angles to each other the two tubular levels (cross levels), of

which one lies parallel and the other at right angles to the axis of the telescope. The construction of the base and the manner of attachment to the tripod are as usual.

DESCRIPTION OF THE TACHYMETER WITH THE PLANE TABLE.—(Tachygraphometer.)

SEC. 20. The general construction of this instrument is shown in illustration No. 33. The telescope transits between the standards; is of 35 centimetres focal length; magnifies thirty-one times, and has double cone-shaped pivots resting in bearings closed by solid covers.

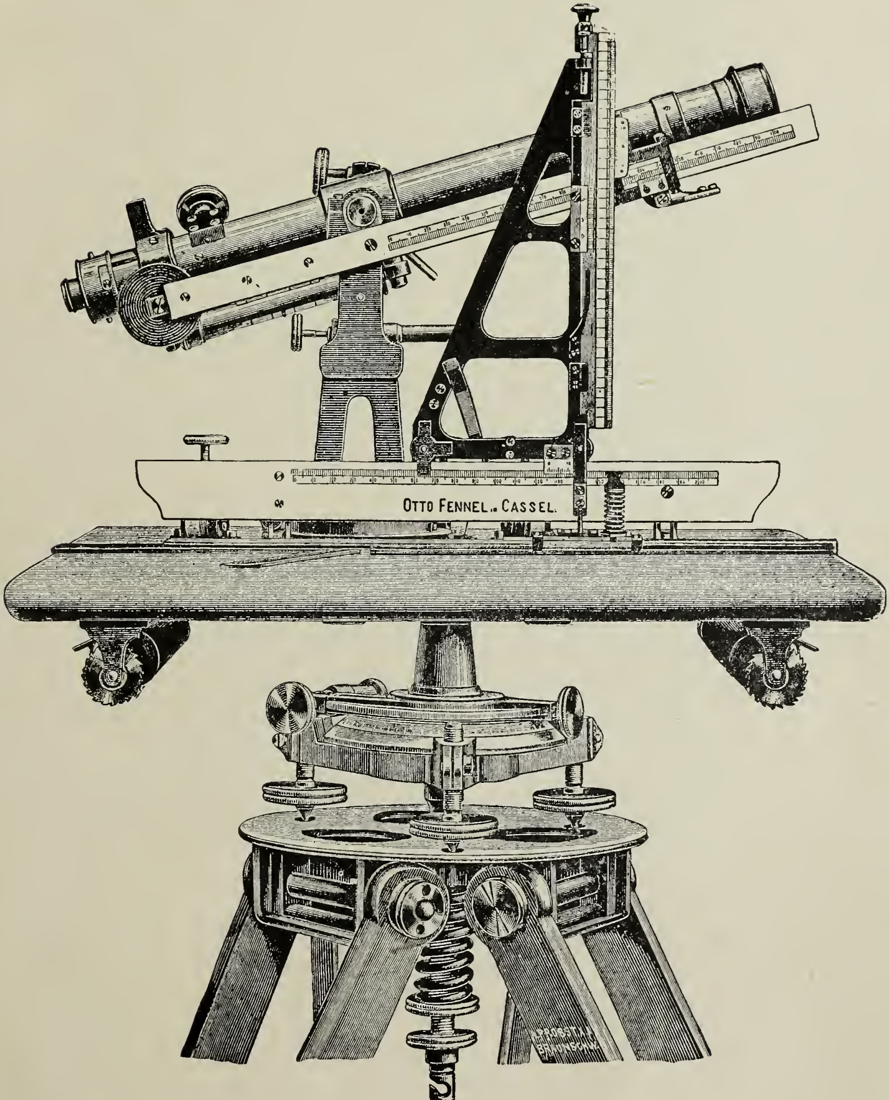
In order to be able to undertake exact leveling the telescope is provided with a reversion level. The eyepiece micrometer is of a peculiar form and so arranged that either of the two outer wires can be brought into contact with the middle wire. The instrument is furnished with two riding levels, one of which is arranged for placing upon the telescope, the other upon the rules. The telescope standard is fastened to the footplate, which corresponds to the rule of the ordinary alidade.

In order to facilitate the motion of the alidade upon the plane table, the footplate is provided with three relieving rollers.

They stand with their axes radial to the axis of rotation of the alidade (which will be further mentioned in section 22) and can by means of vertical set screws be moved so much lower that they project some millimetres below the under surface of the footplate, for which purpose there are corresponding openings in the latter. The rollers not only facilitate the horizontal motion of the alidade upon the plane table but also enable us to keep the alidade in exactly horizontal position while in use, without the necessity of using for that purpose the leveling screws of the table, in the employment of which a new orienting of the table would generally be necessary. One of the relieving rollers has a check screw attached by which the horizontal rotation of the alidade is regulated, *i. e.*, can be made to run easier or harder.

SEC. 21.—The footplate of the alidade is strengthened along its straight side by a flat rib *mm* (Fig. *k*,) upon which a slide can be moved parallel to the scale *BB*, upon which the projection angle runs. To this slide is attached at *g* a slightly projecting vertical socket, in which moves a little cylinder provided at its lower end with a needle and at its upper end with a knob, which cylinder can be moved up and down close along the edge of the footplate. A slight pressure of the finger serves to force the needle down and to mark a point in a paper lying beneath, while upon the removal of the pressure a spiral spring coiled around the socket lifts the needle up again.

By the arm *f*, the slide is connected with the projection angle and it will therefore transfer directly upon the plane-table, in a mechanical way and by means of the needle cylinder, the motions of the projection angle, which correspond in the proportion shown to the horizontal dis-



TACHYGRAPHOMETER

OR

PLANE-TABLE TACHYMETER.

On the Wagner-Fennel Tacnymeter and Tachygrapnometer.

tance of the point observed, without its being necessary to first read this distance from the vernier *c*. (Figs. *k* and *l*.)

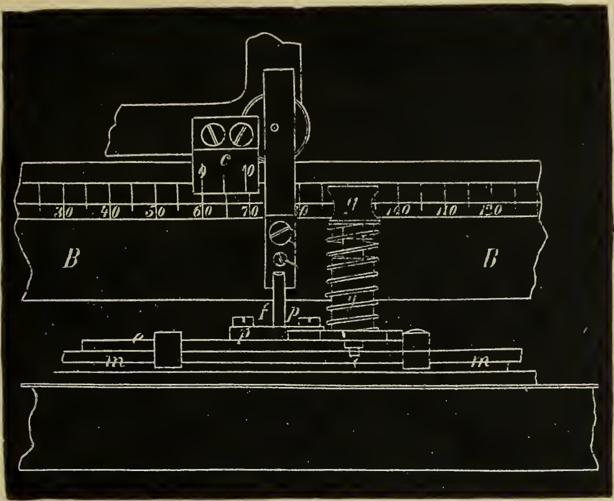


FIG. *k*.

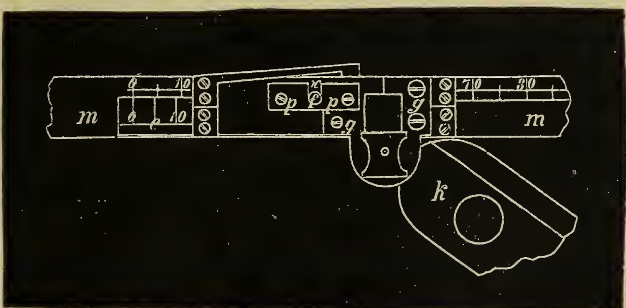


FIG. *l*.

Upon the flat rib *m* there is a scale of distances and upon the slide at *e* is fixed a vernier, which serves for mapping in case the slide should be used independently of the projection angle, for which purpose the arm *f* can then be removed.

This case occurs when it appears desirable to choose the scale of the map smaller or larger than the scale to which the projection apparatus is adapted.

Then the horizontal distances can be read from the vernier *c* and can be set off in corresponding reduction upon the graduation of the rib *m* by the vernier *e*.

In the ordinary use of the instrument, however, the slide remains joined to the projection angle and the graduations of the rule *B B* and of the rib *m m* do not then come into use.

SEC. 22. In order to be able to practically make use of the above process of transforming horizontal distance in graphical delineation, it is, however, necessary, in the first place, that during the observations the alidade should turn exactly about the station point marked upon the table, and that, secondly, the needle cylinder should coincide with this station point when the vernier *e* stands at zero upon the scale of distance, or, if mapping mechanically, the projection angle should stand with its forward edge in the produced axis of the telescope.

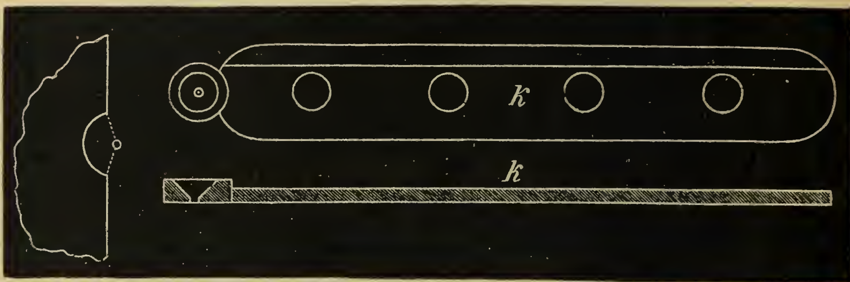


FIG. *m*.

This is accomplished by the aid of a small centering rule *k* (Fig. *m*), whose circular end can be placed over any desired point by means of a little hole at its center. In the straight edge of the alidade rule a circular segment is cut out, the radius of which is exactly equal to the radius of the outer circumference of the end of the centering rule, and with the middle point of which the needle of the cylinder would coincide in the before-mentioned position of the slide.

If we place the head of the centering rule exactly in the opening in the alidade rule, then the middle point of the opening must coincide with the middle of the small hole, and in order to satisfy the requirements of graphic delineation it is only necessary to move both parts until the station marked on the table lies in the middle of the peep hole.

Then the centering rule is held fast with the right hand, while the left hand makes the necessary rotation of the alidade, which motion is very readily accomplished, in consequence of the radial arrangement, with reference to the center of rotation of the relieving rollers mentioned in section 20.

SEC. 23. In plane-table surveys, as is well known, the horizontal angles which the lines of sight make with the line of orientation are transferred directly from the ground to the map fastened upon the table; yet heretofore it was necessary to plot horizontal distances, determined in any manner, by compass and scale along the straight edge of the rule.

But with the above-described mapping apparatus the latter work is avoided, and all the mapping is accomplished in a purely mechanical way without the necessity of any manipulation other than the pressing down of the needle cy inder.

On the Wagner-Fennel Tachymeter and Tachygraphometer.

The concentric setting of the center over the station has properly only to be done once for each position of the instrument, while with some practice it is so quickly done that a frequent renewal of the setting is not a matter of great moment.

The plotting therefore without detriment to a more than satisfactory exactness takes up so little time that it may properly be regarded as the immediate result of the surveying operations.

SEC. 24. The fastening of the paper to the plane table might be accomplished in the usual and well-known manner.

But since in land surveys for the purpose of studying locations a long and narrow zone is generally to be considered, two rollers are attached below the plane table for surveys on long pieces of paper.

In order to increase the adaptability of the instrument, it is so arranged that the alidade can be fastened directly upon the movement. For this purpose three milled-head screws are furnished with the instrument, which pass through adjusting nuts and have corresponding hollow threads in the base of the alidade. (Fig. *n*.)

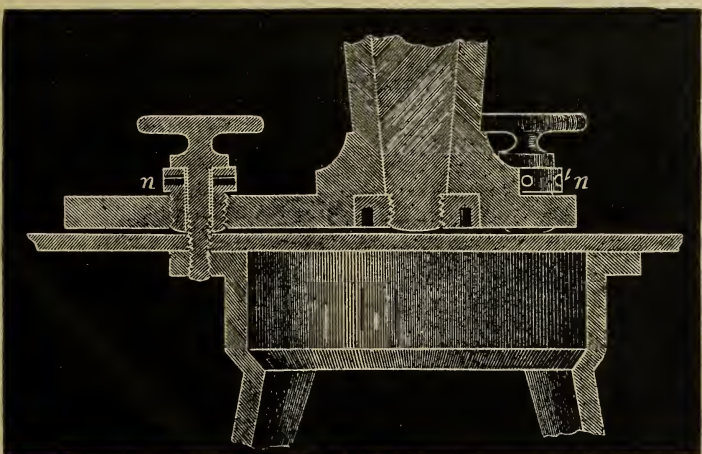


FIG. *n*.

Before the alidade is placed upon the movement and the three above-described screws are tightened, the ivory relieving rollers of the alidade should be screwed up high, so as not to project below the base plate. Then the instrument may be used for leveling, as well as for angular measurements, for which purposes the telescope is provided with a reversion level, and the movement with a horizontal circle whose opposite verniers read to single minutes.

The limb and the verniers lie in one plane inclined to the sight, in order to be conveniently read in any position of the foot plate.

SEC. 25. The use of the instrument is sufficiently obvious from what has already been said, but the following will be repeated:

The setting of the stand over the desired point on the ground, and the leveling and orienting of the plane table, are accomplished according to the regular rules for plane-table work. Then the height of the station above the datum plane is set upon the scale of heights of the projection angle, the relieving rollers are put into action, without, of course, throwing the alidade out of level, and finally the center of motion of the alidade is brought by means of the centering rule over the point on the map corresponding to the station on the ground.

The setting of the tachygraphometer is now complete and the survey proper can be proceeded with, in which for each point to be plotted the following manipulations are to be followed in the order stated:

(*a*) The telescope is pointed to the telemeter held at the desired point and the distance (on the slope) is read off.

(*b*) The slide upon the upper rule *A A* is set by the vernier *b* to this distance.

(*c*) The projection angle is pushed against the vernier *a*.

(*d*) The needle cylinder is pressed down, and—

(*e*) By means of the vernier *a* the height of the distant point is read off and marked at the point plotted upon the map.

Only five separate manipulations are therefore necessary, two of which, however (*c* and *d*), are mere motions of the hand and therefore require no particular attention.

ON HOLDING THE TELEMETER AT RIGHT ANGLES TO THE LINE OF SIGHT.

SEC. 32. The rods which are furnished with these instruments are 4·5 metres long and are graduated on both sides. One side is arranged for measuring distances, and at the height of 1·5 metres it has a special sighting mark, which is the zero point of the scale. The other side is intended for leveling, and has, therefore, a uniformly continuous graduation and numbering, the zero point of which coincides with the foot of the rod. For convenience of transportation, the rod slides together to a length of 1·75 metres.

The correctness of the reading of distances from the rod held at right angles to the line of sight will depend upon its being held correctly and steadily. The observer can readily test whether the rod is held right, since the sighting-blocks, whose upper edges are pointed towards the instruments, are painted black in front, and white above and below. (Fig. *o*.) In the correct position of the rod the observer can see only black surfaces, but if the rod is badly held, a white strip will be seen above or below, whose width will correspond with the amount of error in holding the rod. In this way the holding of the rod is accurately tested when one is in position to read the distance.

On the Wagner-Fennel Tachymeter and Tachygraphometer.

The following method of setting the rod has been found convenient: First, direct one of the edges of the sighting-block upon the instrument, and then bring the bubble of the transverse level to the center, any slight deviation of the edge of the block from the line of sight being at the same time corrected.

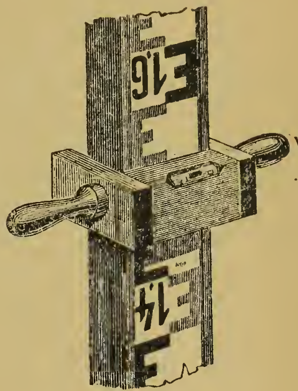


FIG. o.

In training a rodman, he should be required to stand exactly behind the rod and to sight directly at the instrument without twisting his neck, his eyes being about 40 or 50 centimetres from the rod and his arms extended nearly to their full length. In this exact setting the slight angular motion necessary for bringing the level bubble to the center is involuntarily made approximately at right angles to the line of sight, so that the sighting-block is not noticeably, if at all, deflected from the line of sight.

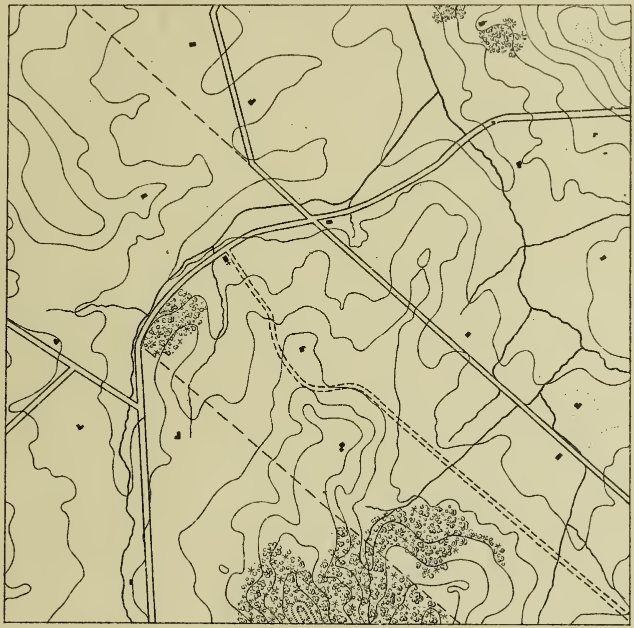
In windy weather it is advisable to use a light brace about 2 centimetres in diameter and 1·70 metres long as a help. This is planted about one-half or three-fourths of a metre from the rod, on the side opposite the wind, and inclined so that the upper end passes behind the handle, to which it is firmly held by the fingers, the thumb holding the brace. While setting the rod in position the brace is held loosely, and is brought into play only when the rod has been correctly placed. A rodman who is not very strong should always carry such a staff, especially as it causes no material loss of time. The rod must be set correctly each time in from three to five seconds, at the longest.

SUPPLEMENT N.

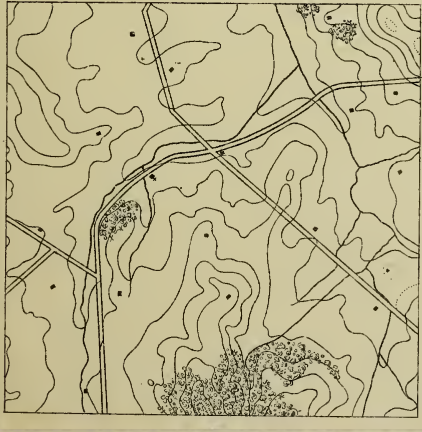
REDUCTIONS UPON DIFFERENT SCALES.

REDUCTIONS FROM THE SCALE OF 1-4800.

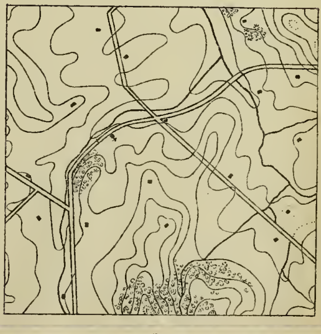
A part of the topographical survey of the District of Columbia, illustrating the power of different scales for the delineation of topographical features, is shown on illustration No. 34. Contour interval of the original District of Columbia survey, 5 feet; contour interval of the reductions, 20 feet; reductions made under the direction of Assistant John W. Donn.



$\frac{1}{20\,000}$



$\frac{1}{30\,000}$



$\frac{1}{40\,000}$

Reductions on different Scales

Contour interval 20 ft.